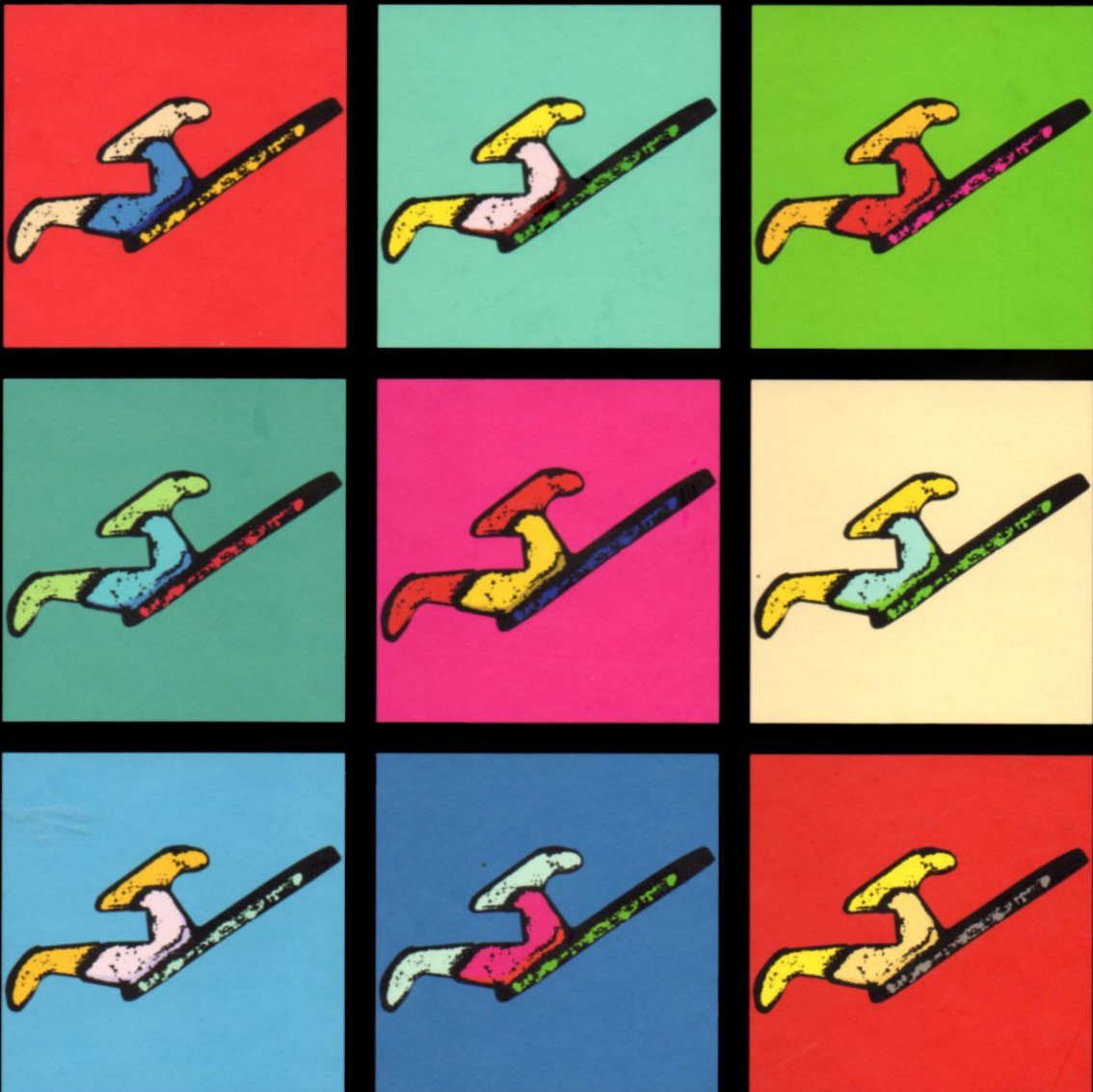


Giuseppe Scuzzo • Kyoto Takemoto

Lingual Orthodontics

A New Approach Using
STb Light Lingual System
&
Lingual Straight Wire



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Giuseppe Scuzzo, Kyoto Takemoto

LINGUAL ORTHODONTICS
A New Approach Using STb Light Lingual System &
Lingual Straight Wire

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A New Approach Using STb Light Lingual System & Lingual Straight Wire

Giuseppe Scuzzo
Kyoto Takemoto



London, Berlin, Chicago, Tokyo, Barcelona, Beijing, Istanbul, Milan,
Moscow, New Delhi, Paris, Prague, São Paulo, Seoul and Warsaw

British Library Cataloguing in Publication Data

Scuzzo, Giuseppe.

Lingual orthodontics : a new approach using
STb light lingual system & lingual straight wire.

1. Orthodontic appliances. 2. Malocclusion-
Treatment.

I. Title II. Takemoto, Kyoto.

617.6'43-dc22

ISBN-13: 9781850971924



Quintessence Publishing Co. Ltd,
Grafton Road, New Malden, Surrey KT3 3AB,
Great Britain
www.quintpub.co.uk

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Editing: Quintessence Publishing Co. Ltd, London
Cover illustration: Dr Gianfranco Mostardi
Layout and Production: Quintessenz Verlags-GmbH,
Berlin, Germany
Printed and bound in Germany

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FOREWORD

It is a great pleasure to present this new lingual orthodontic book written by my friends and colleagues Giuseppe Scuzzo and Kyoto Takemoto.

This new text carries on from the previous *Invisible Orthodontics* and represents the rapid evolution of the lingual technique, especially regarding management of comfort and treatment mechanics using the new STb Light Lingual System, and the improvement in laboratory approach.

All the cases presented in this book were treated according to the principles of the treatment that can be applied to the various problems encountered in clinical practice, demonstrating the long experience of the authors.

In my opinion this book is a valuable contribution to orthodontics, for both practitioners and students; for this reason, in the Orthodontic School of the University of Ferrara, we have decided to adopt this textbook for the lingual orthodontic postgraduate course. I hope that other orthodontic schools will follow our example.

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DEDICATION

This book is dedicated to our families for having made this work possible through their encouragement, love and patience.

We would also like to thank and express our gratitude to our staff, in particular Mr. Alberto Massucci for his invaluable help in the assembly of this book.

1 INTRODUCTION

The development of numerous orthodontic techniques, together with notable progress from a commercial technological point of view, have led to the achievement of exceptionally high orthodontic standards. In fact, there are now no limits to the solution of any kind of malocclusion, whether dental or skeletal, with a high percentage of success. The easy availability of various sources of information has increased public interest not only about forms of esthetic dental treatment but also about prevention of caries and periodontal disease. In the pre-prosthetic field, orthodontic therapy has led to solutions for problems that previously greatly limited the quality of tooth implants. Furthermore, the recent discovery of a link between the occlusal area and other body zones, mediated by means of muscle tissues, has strengthened the concept of treatment that can improve the well-being of a person, not only in a limited area but also in the body as a whole. Moreover, demographic and cultural changes during the past few years have contributed to a new chapter in orthodontics.

Not so long ago, orthodontic therapy was seen by the public, and by many orthodontic operators, as a treatment for children or for patients within a certain age range. In some countries the drop in the birth rate and the increase in the average age of the population have focused operators' attention on alternative age groups for orthodontic therapy. As a result, the industry has tried to improve the esthetic aspects of the apparatus by introducing miniaturized brackets, in plastic or porcelain, in an attempt to make the treatment period esthetically satisfactory.

However, invisible (lingual) orthodontics represents the only solution for patients from an esthetic

point of view. All patients – not only adults – attach great importance to their appearance and several of them would probably refuse traditional orthodontic treatment for social or work reasons. As a result of the influence of the media, our esthetic features have increasingly become points of reference for our social relationships. A pleasant esthetic look increases a person's self-confidence and provides reassurance when making personal contacts. It also helps interpersonal relationships, since initial contact is visual. Today, more than ever, patients are aware of protruding teeth, overcrowding, and diastemas, which can cause psychological problems related to laughing or smiling. To be good-looking is always an advantage, especially in relationships between adults. The better looking a person is, the more positive is their assessment by others: all of which helps to reinforce a feeling of personal worth. Thus the esthetic aspect is the most frequent motive for seeking orthodontic treatment, and patients will not accept an orthodontic result with perfect occlusion if it does not improve their facial profile. It would be unusual to come across a patient who claimed that they are not interested in improving their esthetic aspect and was only interested in having their occlusion corrected. The reverse, however, is encountered frequently.

Today, the main goal of orthodontic treatment is to achieve facial balance, and the orthodontic treatment plan has to provide a balance between esthetical treatment, functionality, and a patient's aspirations. Adhering rigorously to skeletal goals of treatment is considered an error in modern orthodontic philosophy. As stated above, esthetic aspirations are now universal, including both male and female adolescents. In this regard, the highly

esthetic invisible orthodontics has a fundamental role in achieving treatment goals: a smile revealing esthetic harmony is very important at an age as difficult as adolescence.

Lingual orthodontics is today a reality and represents the best solution for meeting the needs of patients without the risk of compromising biomechanical efficiency. In fact, in some kinds of malocclusion, it increases efficiency. Thus, knowledge of lingual orthodontic treatment needs greater dissemination among orthodontists. At present, the various lingual techniques are practiced by a small group of practitioners and there is little sharing of the skills in published literature to achieve consistency between the various types of lingual orthodontic techniques. Standardization will help more orthodontists appre-

ciate and confidently apply these new techniques. This is because many orthodontists have found lingual orthodontics difficult to use and limited in application. This has stopped them from exploring the method, but it should be recognized that the lingual approach requires only slightly different biomechanical knowledge from buccal techniques.

During the past few years, the work of a few specialists has led to the systemization of the main steps of the lingual technique, as well as of the labial technique, allowing an easier approach for less experienced orthodontists. Many universities and orthodontic societies around the world are now beginning to offer lingual orthodontic courses, and this approach should become part of every orthodontist's armamentarium.

2 OVERVIEW OF BRACKET AND APPLIANCE SYSTEMS FOR LINGUAL ORTHODONTICS

Introduction

Until today, it was not possible to conceive an ideal, standardized bracket that would perform equally well for all kinds of malocclusion and reconcile the orthodontist's biomechanical requirements with the patient's need for greater comfort. Throughout the various generations of brackets, we have been witnessing multiple changes in their shape and size, and yet the dilemma remains of how to improve comfort while maintaining good three-dimensional (3D) tooth control.

The comfort-related problems can be summarized as follows:

- presence of (especially anterior) prematurities
- difficulty in maintaining oral hygiene, resulting in the formation of plaque and gingival inflammation
- limitations in the correct pronunciation of some phonemes, especially labio-dental (F, V), alveolodental (T, D, N), and alveolar (S, Z, R, L) sounds.

The first problem in the list above has most influenced the strategic choices made by manufacturers of orthodontic appliances. American Orthodontics (USA) and Forestadent (Germany) have both opted for miniaturized brackets, thus avoiding potential anterior prematurities, whereas other companies such as ORMCO (USA), through the Kurz 7th generation brackets, have provided for unavoidable prematurities to be as uniform as possible by means of a flat and rigid bite plane. However, this statement is contentious because the bite plane has been studied in ideal conditions, rather than in conditions of malocclusion. The typical Kurz 7th

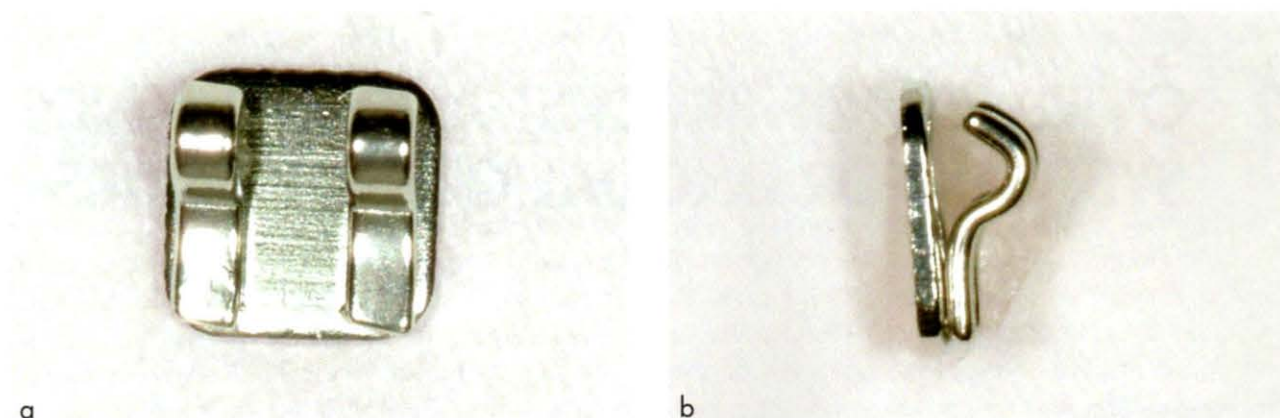
generation bracket bite plane has become part of a biomechanical strategy that uses occlusal forces as intrusive forces in the treatment of deep bites to produce a temporary disclusion of the posterior segments, allowing these teeth to move faster.

Although Kurz 7th generation brackets have a primary role within the framework of lingual orthodontics, in many cases they cannot be considered as the brackets of choice, for example for controlling rotation and in alignment cases. These brackets inevitably need indirect bonding by means of a set-up, and cannot be assumed to be "comfortable" for the patient simply on the grounds of their reduced thickness. Therefore, our clinical experience has led us to believe that, in some patients, the degree of difficulty of the diagnosed malocclusion precludes the use of these brackets.

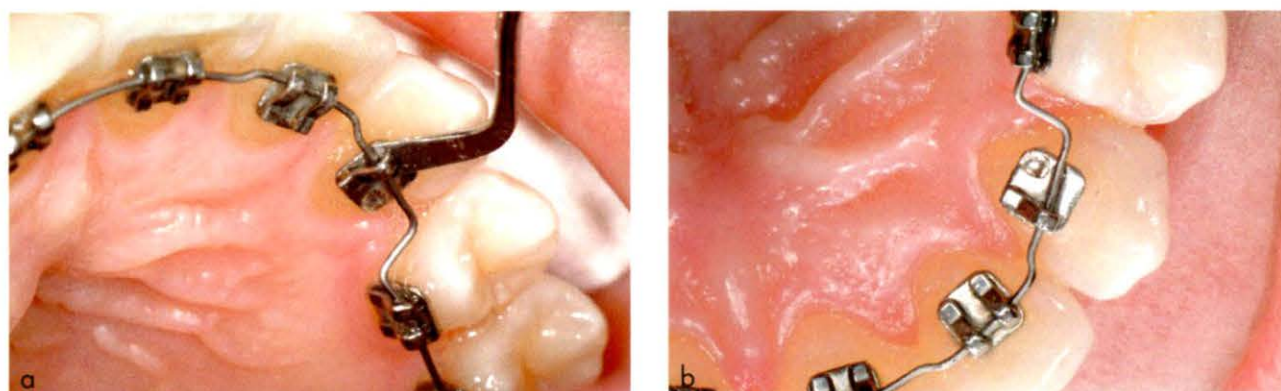
2D Lingual Brackets

2D lingual brackets (Figs 2-1a and 2-1b) were introduced by Professor J. Philippe. These brackets come in three sizes and have a very broad base with a mesh supporting one, two, or three electro-welded tie wings. These brackets can be left *in situ* at the end of the treatment (to act as a bonded retainer).

When the individual tie wings are closed, the 2D bracket slot functions exclusively as a round slot in which the orthodontic wire has ample clearance to move freely. The tie wings are closed with Weingart pliers, and opened by inserting a small spatula between the wing and the base (Fig. 2-2a), making the bracket self-ligating. It should be noted, however, that if the 2D bracket is used as a lingual bracket, it provides only two-dimensional control.



Figs 2-1 2D bracket: (a) anterior view; (b) lateral view.



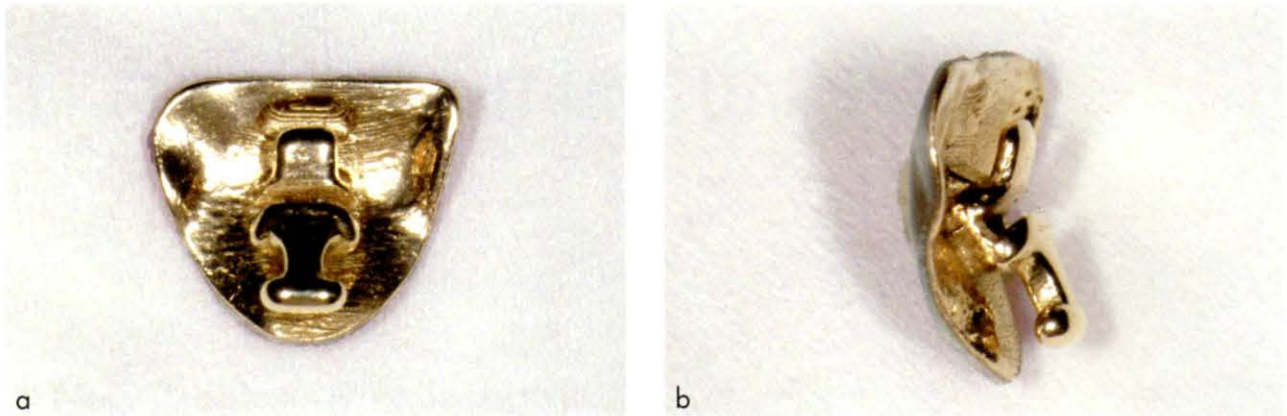
Figs 2-2 (a) A 2D bracket wing being opened by inserting a small spatula between the tie wing and the base. (b) Close-up of the broken tie wing.

In our experience, the positive feature of the Philippe bracket is that it facilitates rotation control. The vertical insertion of the orthodontic wire allows ample control of this type of movement. Of course, this type of bracket does not fulfill every expectation, but in the hands of the experienced orthodontist with superior wire-bending skills, good results can be obtained in most patients.

In spite of its biomechanical shortcomings, we have used the 2D bracket to treat mild and, sometimes, moderate malocclusions with rotations, diastema, and anterior crowding. The brackets can be bonded using a simple indirect transfer system prepared at the orthodontic prac-

tice laboratory or, in the simplest cases, they can be bonded directly. However, if on the one hand these brackets have the advantage of not needing complex laboratory set-up methods, on the other hand they fail to provide 3D tooth control, as owing to their intrinsic design they lack a proper rectangular slot to manage tip and torque control.

Indeed, with this type of bracket, it is extremely difficult to close the extraction sites by mesiodistal tooth movement, to control torque (especially in the anterior segments during en-masse retraction), and to accomplish controlled tipping movements. It is also difficult to control second-order move-



Figs 2-3 (a) A customized lingual bracket showing the archwire slot. (b) Lateral view of the customized lingual bracket.

ments (vertical control) because of the large amount of play of the orthodontic wire within the round bracket slot, which greatly reduces the net intrusive and/or extrusive movement. So if these movements are desired, exaggerated bends in the archwire are necessary. This, in turn, requires additional wire bending to compensate for the counter-effects of the intrusive and extrusive forces (ie, retroclination and proclination, respectively).

The small size and simple design, however, make 2D brackets very comfortable for the patients, even though there are some difficulties in managing the appliance, especially with regard to the durability of the wings (we found that the wings break after repeated activation [Fig. 2-2b]) and bracket debonding, owing to the non-anatomical design of the base. Therefore, although 2D brackets have proved effective in treating a great proportion of mild to moderate malocclusions, we do not advise their use in patients with more complex malocclusions that require more precise tooth movements.

Customized Invisible Fixed Appliance

More recently, the 100% customized invisible fixed appliance system has been introduced on the market. In this lingual appliance system (Incognito™ [TOP-Service für Lingualtechnik, Bad Essen, German]/iBraces® [Lingual Care, USA] [Figs 2-3a and 2-3b]) the bracket bases are customized for each tooth of each patient, which provides both superior comfort for the patient and predictable clinical results requiring minimal adjustments by the orthodontist.

A two-phase impression of the patient's teeth is required to make the models on which the customized brackets and the bonding tray are fabricated. Before fabrication, a trained laboratory technician sets up the teeth on the model, based on Andrews' six keys of occlusion. The set-ups are scanned into a computer, and the brackets are designed using specially designed CAD/CAM software. The customized Incognito/iBrace brackets are then printed out using 3D printing technology and cast using the latest prototyping machines. The brackets are placed on the patient's original models and bonding trays are made for indirect bonding.

The archwire geometry is also determined using the computer software following which each archwire is individually shaped to high precision using wire-bending robots.

3 STB AND LIGHT LINGUAL SYSTEM

A New Treatment Philosophy with a New Lingual Bracket

In the attempt to improve our patients' quality of life during treatment, the "Light Lingual" philosophy was born: a "light" lingual technique allowing very fine control of tooth movement to achieve maximum occlusal, functional, and cosmetic results, while minimizing the effects on the patient's social life. With Light Lingual patients are able to forget they are wearing a fixed orthodontic appliance, not only when looking at themselves in the mirror, but also when speaking. Although all lingual appliances in general can be considered as invisible appliances that allow the patient to have a beautiful smile even while undergoing orthodontic treatment, the Light Lingual philosophy gives patients a better reason for smiling, as it enhances patient comfort without compromising clinical results.

However, it should be noted that the Light Lingual technique does not relieve the orthodontist of their professional responsibilities. Lingual orthodontics should not be seen as a technique in which all that is required of the operator is to replace wires – just as aligners cannot be considered as replacements for conventional orthodontic appliances. Like the medical profession, several elements are vital to an orthodontist's professional makeup: the trained eye, diagnostic skills, therapeutic strategy, and clinical experience, and also dexterity in performing adjustments required during treatment. As stated above, besides improving the patient's quality of life, it is important that developments in techniques enhance the orthodontist's work as well by simplifying clinical

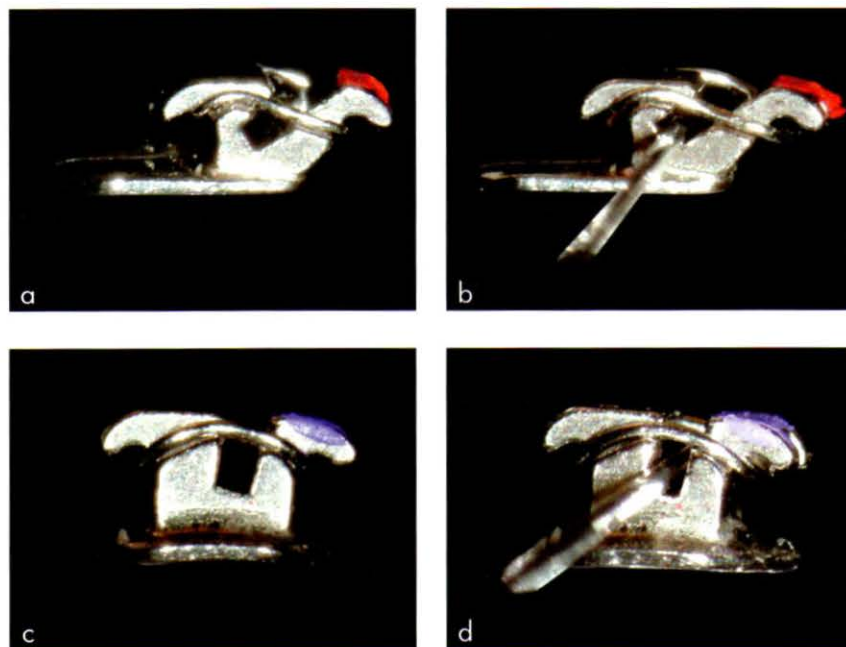
techniques, where this is feasible, and by simplifying the sophisticated and costly laboratory work involved.

The low technology approach means working with a bottom-up approach, starting from the basics, scaling up sophistication in response to requirements of individual patients, and only when needed. The fact that we have sophisticated technology at our disposal does not mean that we can use it indiscriminately in all cases. Using such technology to solve simple problems can have undesirable consequences as complex mechanisms may trigger, for example, unwanted movements, which are more difficult to control and manage than the original problem.

Development of a New Lingual Bracket

The reasons described in the previous section stimulated the authors to develop a new, simple, but "revolutionary" lingual bracket, called STb (Scuzzo-Takemoto bracket, after the inventors' names). The STb has the following features:

- small size with a smooth surface and a small slot width with increased inter-bracket distance, minimizing patient discomfort
- lateral wings to facilitate rotation control
- rectangular slot (0.018 × 0.025) so that a square or rectangular wire may be used if necessary
- extensions on the mesial and distal sides of the slot (called passive ligation "steps"; Figs 3-1a to 3-1d) to prevent the metal ligature from pressing the engaged wire deep into the slot: this means



Figs 3-1a-d The 0.3 mm extensions ("steps") on the mesial and distal sides of the slot allow passive ligation by preventing the metal ligature from pressing the engaged wire deep into the slot.

there is no binding effect and the wire can slide freely in a low-friction system when using light orthodontic wires (0.010 to 0.014).

With this type of bracket system we can use the traditional indirect set-up method, that is, Custom Lingual Appliance Setup Service (CLASS), or transfer systems with the Torque Angulation Reference Guide (TARG) system, DALI (Drawing Arch Lingual Ideal) and Slot Machine (Creekmore, USA) programs, or Torque Angulation Device (TAD)/Bracket Positioning Device (BPD) positioners. Following this, we use full-size rectangular wires to achieve better three-dimensional control.

We also have the option of a direct, simplified bracket set-up, without the need for the complex laboratory procedures mentioned above, in simple cases in which torque control is not required. In this method, superelastic nickel titanium (NiTi) round wires are used for two-dimensional control during treatment, and a square or rectangular wire is only used to control the torque in particular arch segments or in individual teeth. In this way the bracket acquires greater biomechanical versatility to suit different clinical needs (ie, in the "Social 6" cases, see Chapter 15). Of course, the indirect set-up

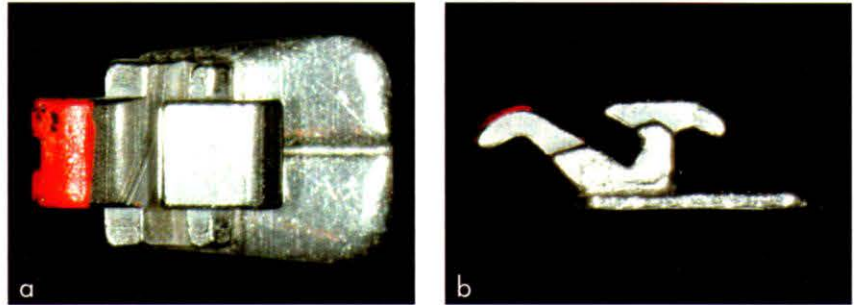
methods can be used in all cases, and must be used in all extraction cases.

Although having a very flat profile (1.5 mm), the hook-shaped tie wings of the bracket easily accept conventional metallic or elastic ties and elastic chains. This greatly reduces chair-side time and improves patient comfort; the orthodontist is spared the need for double over-ties that are typically required for the Kurz 7th generation bracket (ORMCO, USA). The easy tying operation can be entrusted to the clinical assistant.

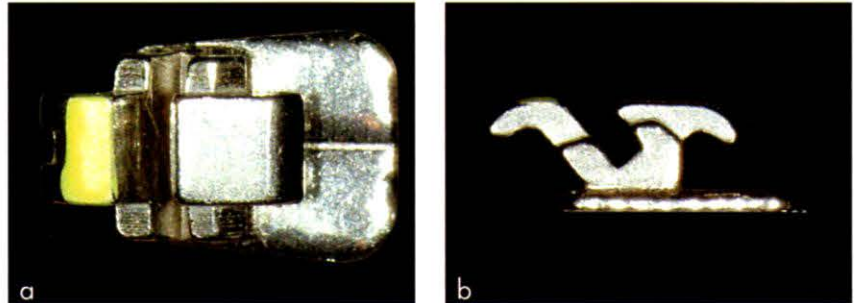
The innovative low-friction design allows the tie to be non-binding and prevents the wire from being squeezed against the slot (for small to medium wire diameters). Thus friction is markedly reduced and the wire can slide easily through the slot. These mechanics are a clear departure from most other lingual brackets, including the Kurz 7th generation brackets featuring the high-friction double over-tie, which results in a strong binding effect.

Another feature of the STb system is that the same brackets are used on all the teeth within a particular segment of the dental arch, which makes operation easier and improves the ergonomics of the appliance. In addition, there are no differences in the built-in tip and torque for the individual teeth in both

Figs 3-2 Anterior teeth universal STb brackets, 55 degrees torque: (a) anterior view; (b) lateral view.



Figs 3-3 Anterior teeth universal STb brackets, 40 degrees torque: (a) anterior view; (b) lateral view.



arches, unlike the labial straight wire techniques. The bracket types are as follows:

- one bracket type for maxillary anterior teeth including the canines
- one bracket type for mandibular anterior teeth including the canines
- one bracket type for all premolars
- one bracket type for mandibular molars
- one bracket type for maxillary molars (which differs from the bracket for the mandibular molars because of a 5 degrees distal offset and 10 degrees of torque).

Technical Specifications of the Various Types of STb Brackets

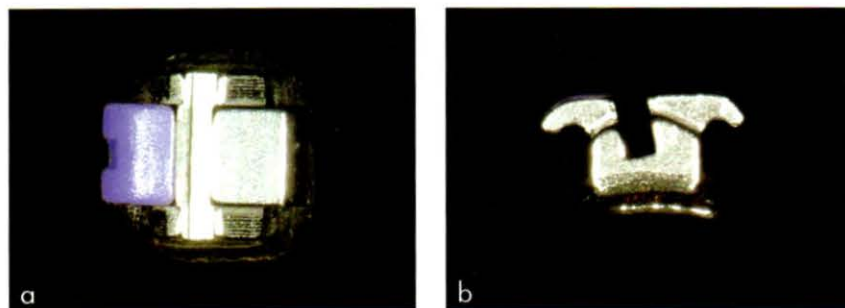
Anterior Brackets (Maxillary and Mandibular)

There are two types of STb anterior bracket to allow for the differences in lingual tooth morphology. The brackets have a thickness of 1.5 mm and two different degrees of torque: 40 degrees and 55 degrees; none of these brackets is pre-angulated.

The 55 degrees bracket is used in extraction cases where greater torque control of the crowns is necessary (Figs 3-2a and 3-2b). The 40 degrees bracket (Figs 3-3a and 3-3b) is generally used for the mandibular anterior teeth, but it may be used for the maxillary anterior teeth as well.

The anterior bracket slot size is 0.018 × 0.025 and the slot width of the bracket is 1.5 mm. The brackets are available with or without hooks and they do not have a bite plane; therefore there is less chance of occlusal interference in the anterior segment.

The 0.3 mm extensions on the mesial and distal sides of the slot allow passive ligation of round



Figs 3-4 Maxillary/mandibular first and second premolars universal STb brackets, 11 degrees torque: (a) anterior view; (b) lateral view.

wires ranging in size from 0.010 to 0.014, which are not pressed deep into the slot (as is the case for conventional lingual orthodontic brackets), so the resulting mechanism is friction-free or low-friction.

Premolar Brackets (Same Size – Maxillary and Mandibular)

The same bracket is used for the first and second premolars of both arches (Figs 3-4a and 3-4b). It has a thickness of 1.5 mm with +11 degrees or 0 degrees of torque and 0 degrees of angulation, and a slot width of 1.5 mm.

This bracket also has the 0.3 mm extensions, which make it low friction or friction-free like the anterior brackets. The brackets are available with or without hooks.

Maxillary Molars

The first molar bracket is a double convertible bracket with a removable cap (Figs 3-5a to 3-5c), while the second molar bracket is a terminal buccal tube (Figs 3-6a to 3-6c). They have +10 degrees torque and 0 degrees angulation. There is a distal offset of 5 degrees to prevent distal rotation. Because of this distal offset, there are different brackets for the maxillary right and left molars. These brackets are available with hooks.

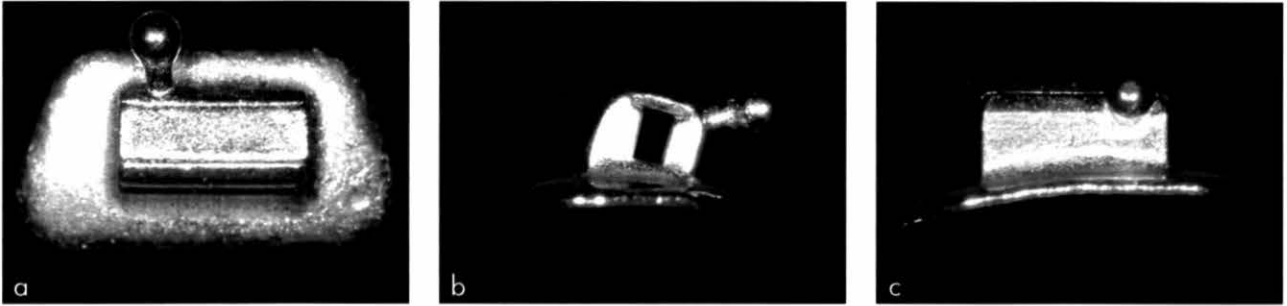
Mandibular Molars

The bracket for the first mandibular molar is convertible too (Figs 3-7a to 3-7c), and the second molar bracket is a terminal buccal tube (Figs 3-8a to 3-8c). Both have 0 degree torque and no distal offset; therefore the same bracket is used for the right and left sides.

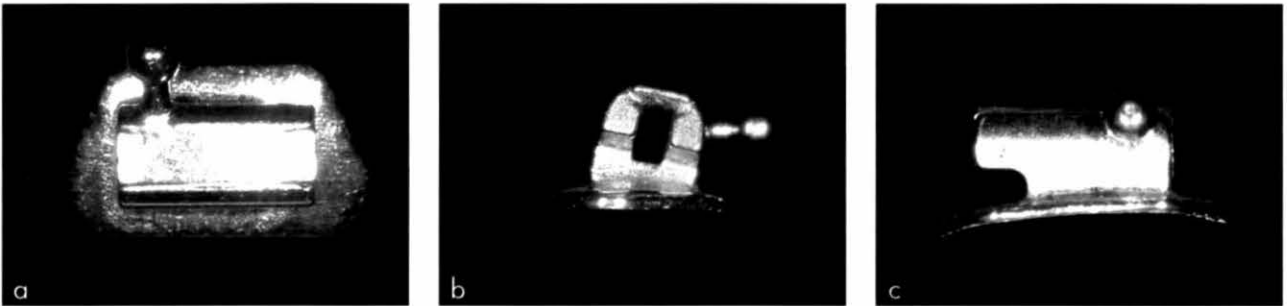
The Light Lingual System

Every orthodontist wants to conclude treatment with the best functional and esthetic results, using methods that cause the least possible distress to the patient and that require minimum compliance. Light forces are the answer to the orthodontist's needs. Today we can use NiTi, copper NiTi (CuNiTi) wires, etc., whose main feature is elasticity. These wires are widely used with the new self-ligating techniques. We believe that the use of low-friction STb brackets in association with extra-light wires producing light forces is paving the way for a new revolution in modern orthodontics. Light forces are both beneficial for dentoskeletal structures, as explained in Chapter 5, and facilitate the whole treatment, for example, less anchorage is required.

Clinical observations have provided evidence that these brackets produce less friction: the "passive ligation steps" (the 0.3 mm extensions on the sides of the bracket slots) result in ties with decreased friction, which allows the application of lesser forces. This, in turn, translates into no or minimal reaction forces. Clinical analysis of the patients treated with



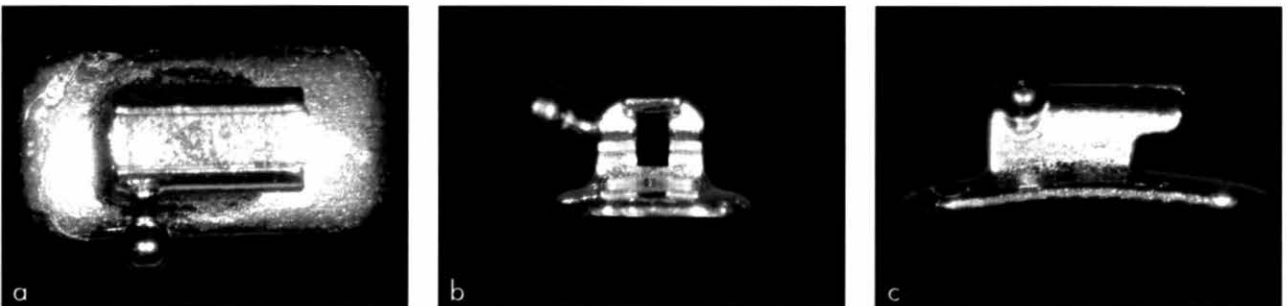
Figs 3-5 Maxillary first molar universal STb bracket/tube (convertible): (a) anterior view; (b) distal end view; (c) lateral view.



Figs 3-6 Maxillary second molar universal STb buccal tube: (a) anterior view; (b) distal end view; (c) lateral view.



Figs 3-7 Mandibular first molar universal STb bracket/tube (convertible): (a) anterior view; (b) distal end view; (c) lateral view.



Figs 3-8 Mandibular second molar universal STb buccal tube: (a) anterior view; (b) distal view; (c) lateral view.

STb has shown that in most cases the control exerted by the musculoskeletal structures is sufficient to prevent unwanted displacements.

The light forces associated with non-frictional techniques produce faster movements with less trauma to the anatomic structures and prevent hyalinization, thus decreasing patient discomfort. Patient compliance becomes less important as external anchorage devices are not needed to control unwanted movement. These systems are especially effective during the initial steps of treatment – alignment and leveling – as they provide the minimal force required to stimulate cell activity, as advised by Proffit.

To correct transversal discrepancies, it is important to consider the option of expansion, which can be considerable in the maxillary arch, but is more limited in the mandible because of its "U" shape. The amount of expansion attainable with STb brackets and extra-light wires is determined by the outermost position of the teeth with the greatest buccal tip. The wire, sliding freely through the slot, allows the repositioning of the most lingually or palatally displaced or inclined teeth because of expansion of the arch in both the transverse and sagittal planes, and the outermost teeth – generally the canines – provide anchorage. Thus the treatment plan should identify the areas where teeth can move along the mesiodistal axis of the arch; especially, the area behind the molars should be considered and the third molar space, keeping in mind that a missing

third molar allows recovering space by means of the distal movement of the second molar.

Consequently, the STb Light Lingual treatment method involves use of only superelastic round wires (0.010 to 0.014 NiTi or CuNiTi and 0.016 titanium molybdenum [TMA]) or rectangular wires. In the initial steps of the treatment, very light wires are used for leveling, alignment, and derotation. Both the upper and lower superelastic archwires convey a very light, biocompatible force to the teeth – the minimum amount needed to stimulate cell activity without jeopardizing the integrity of the periodontal ligament vasculature, favoring natural settling of occlusal interdigitation. STb brackets accept 0.008 metal ligature ties, low-thickness elastic ties (Power O, SDS ORMCO, USA) and 0.08 to 0.09% extra-light elastic chains; the 0.008 metal ligature ties are recommended especially at the beginning of the leveling stage to maximize the low-friction effect of the brackets.

It is advisable to shape omega loops or put "crimpable stops" on the archwires mesial to the first molars to facilitate sagittal expansion mechanics, and to facilitate alignment by reducing friction in the areas where teeth are in contact during the first stages of treatment. This is achieved by interdental stripping of the mandibular lateral incisors (compliant with Peck's index) as well as the first and second mandibular premolars. These procedures, in addition to the low-friction system of STb brackets and light archwires, results in rapid tooth movement.

4 MECHANICAL ASPECTS OF STB AND OTHER LINGUAL BRACKETS: SLOT PRECISION AND TORQUE STABILITY

Dagmar Ibe & Dietmar Segner

Introduction

One of the advantages of fixed appliances is that it is possible to apply forces in all three directions and apply moments around all three axes. One of the most important moments is the third-order moment or torque, which in lingual orthodontics not only controls the buccolingual inclination of the teeth but also controls the vertical position of the incisal edges or buccal cusps. As all current lingual brackets are based on the edgewise system, archwires with rectangular cross-section are used to transmit the torsional moments from the archwire to the tooth. The effect of the geometric torque depends on the play between the archwire and the bracket slot and on the ability of the bracket to withstand the forces associated with torsional moments. Problems arise if the play between the archwire and the bracket slot is too large or is inconsistent. Another possible source of problems is that the brackets may not be strong enough to withstand these forces and the slot opens up with use.

This chapter describes the results of two in vitro investigations of lingual brackets. In the first study, the slot height of several different types of new lingual brackets currently available on the market was measured using end gauges. In the second study, batches of upper right incisor brackets and upper left molar brackets were mounted in a test apparatus and torsional moments were applied using a 0.018×0.025 (nominal) stainless steel wire. At the same time, the amount of twist in this wire was recorded. From the twist-moment diagrams it was possible to determine when the brackets started to deform permanently or opened up completely.

In today's competitive market, a number of different lingual brackets with different slot sizes are being produced by a variety of manufacturing processes. This makes it difficult for a clinician to decide which type of lingual bracket or technique to adopt. In addition, doctors have to take into consideration their patients' high expectations regarding the treatment. These patients typically attach great importance to the perfection of the finished result (Figs 4-1a to 4-1c) and will not accept a compromised esthetic or functional result. In order to fulfill these expectations, clinicians not only need specialist knowledge and training in lingual technique, they also need an appliance of the highest possible precision, accuracy and small size.

As it is difficult for the orthodontist to evaluate the slot of a bracket without specialized tools, we conducted a study with the aim of testing the slot sizes of a number of brackets available on the market. The precision of the slots was measured using high-precision end gauges. The results of our study showed that there were remarkable differences between the brackets supplied by different manufacturers and there were also variations within brackets from a single manufacturer. Our measurements are meant to help clinicians to choose appropriate brackets from the large variety of bracket designs available to suit their particular clinical needs. Treating patients successfully with the lingual technique depends on the precise interaction between archwire and bracket slot among other things.

It is usually assumed that the brackets we use in orthodontics are strong enough to transfer, without any problems, the forces and moments generated by the archwires. This, however, is not as assured as it might appear. The application of torque in



Fig. 4-1a Pretreatment intraoral photograph of a patient with a problem of different axial inclinations of the upper central incisors.



Fig. 4-1b The upper central incisors at end of treatment.



Fig. 4-1c The patient's smile at the end of treatment.

particular may be associated with large stress moments within the brackets as can be seen in the occasional fracture of ceramic brackets when torque is applied, or, more frequently, when a steel wire is inserted into a ceramic bracket in a situation where there is a discrepancy in the third-order angulation of the slot and the archwire. As lingual brackets are often smaller in size than their labial counterparts, it was felt that it was even more necessary to check whether they can withstand any torsional forces that may be applied during an orthodontic treatment.

Basic Considerations

The use of precise appliances is important to optimize the results and reproducibility of orthodontic treatment. Torque application in lingual orthodontics is much more important (and difficult) than in conventional labial orthodontics. Precise application of torque is important for achieving the correct axial inclination of the teeth with conventional labial techniques (Fig. 4-2) but it is frequently absolutely essential in the lingual technique (Fig. 4-3) because the vertical position of the incisal edges or buccal cusps is highly dependent on the amount of torque that is delivered by the bracket.

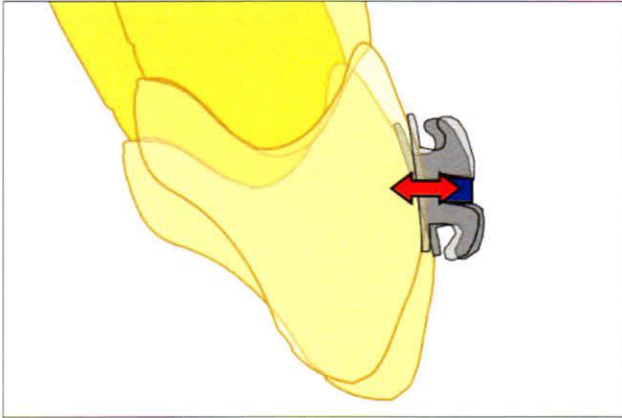


Fig. 4-2 Small vertical change in incisal edge position due to torque error in conventional technique.

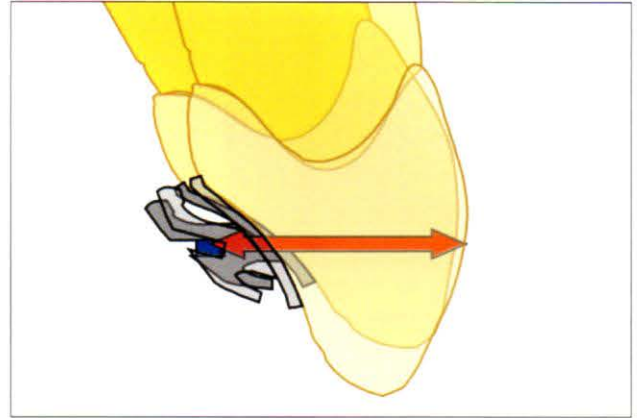


Fig. 4-3 Large vertical change in incisal edge position due to torque error in lingual technique.

Figure 4-2 shows an upper incisor bonded with a conventional twin bracket on the labial side of the tooth. It is clear from this illustration that rotation of the tooth around the axis of the wire as a center of rotation – as happens during the application of torque – will result in a change in the vertical position of the incisal edge. As the distance between the bracket slot and the tooth surface is quite small, so is the amount of vertical change. Also, if the axial orientation of the tooth is not as desired, for example due to torsional play, the vertical error will be small.

In the lingual technique (Fig. 4-3) the distance between the axis of the wire/center of rotation and the tooth surface is obviously larger than with the labial technique, and therefore can lead to a much larger vertical error, especially for the upper incisors. This was also described by Stamm and co-workers (2000), who stated that vertical discrepancies often are attributable to incorrect torque inclination of teeth.

The mathematical relationship (Fig. 4-4) is a simple geometric one and can be calculated using the formula:

$$r = \sqrt{h^2 + d^2}$$

$$\alpha = \tan^{-1} \frac{h}{d}$$

$$\Delta h_1^\circ = h - (r \cdot \sin(\alpha + 1^\circ))$$

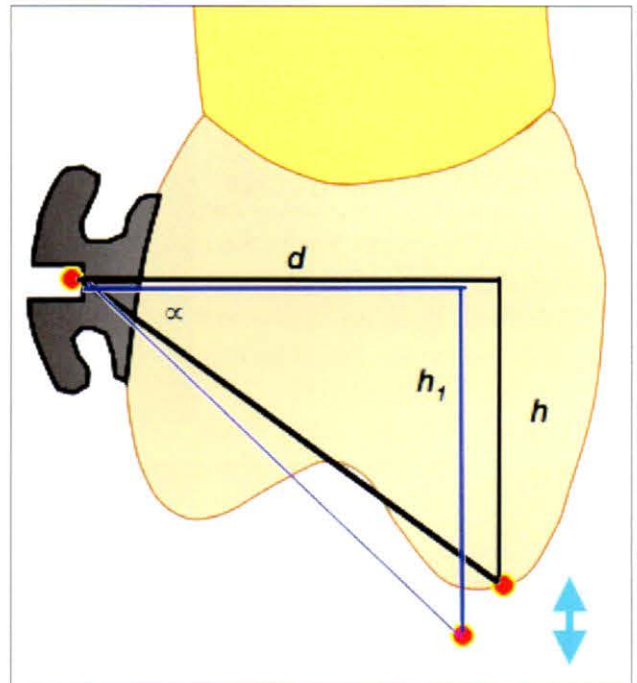


Fig. 4-4 Geometric correlation between axial inclination/torque and vertical tooth position.

The larger the distance from the cusp to the slot (as the center of rotation) the more pronounced will be the influence of a torque error in the bracket's set-up.

The most comprehensive considerations about the factors influencing precise delivery of torque can be found in Meling's thesis "On Torque" (1997).

For precise delivery of torque – both in lingual and labial orthodontics – the amount of play between the orthodontic archwire and the slot should be as small as possible. However, it still must be possible to insert the archwire into the slot without problems. To find out how much play exists between a slot and an archwire it is necessary to know the exact dimensions of the wire, its edge bevel and the slot dimension. With these data it is possible to calculate the play of a given archwire in a measured slot with regard to the edge bevel (Meling et al 1998).

With the help of a computer program based on these formulas, written by the authors, play was calculated for all wire and bracket combinations. For the calculation of each bracket and wire combination an average edge bevel/curve radius of the wire edge of 0.002" (0.0508 mm) was assumed. This mean value is taken from Meling, who measured the edge bevel of wires from different manufacturers. He measured wires manufactured by Dentaureum (edge bevel 0.00180" = 0.0457 mm) and by GAC (0.00285" = 0.0724 mm). The larger the curve radius, the easier it is for the clinician to insert the wire. Some edge bevel is necessary in wires used intraorally because otherwise the soft tissues of the cheek and tongue would be injured by the sharp edges of the archwire.

However, a larger edge bevel will obviously lead to a larger play – the maximum edge bevel is found in a round archwire that simply rotates in the slot and therefore is not capable of delivering any torque. Therefore, it is of interest to the clinician to work with the most precise brackets available and with archwires with an optimal and precise edge bevel.

As mentioned above, precise tooth positioning, especially in the lingual technique, is dependent among other factors, on precise and accurate slot (and wire) dimensions and on the mechanical stability of the brackets to transfer the torque moments from the archwire to the teeth. Measuring slot sizes with precision gauges in the study described above was a rather low-tech procedure. However, the test for torque stability required a more sophisticated testing apparatus that allowed the mounting of many different kinds of lingual bracket, some with vertical

and some with horizontal slots and often with very high torque values of 40 degrees to 50 degrees torque in the base.

The test apparatus developed by Ødegaard and co-workers (1993) was modified for the particular requirements of measuring lingual brackets. Batches of upper right central incisor brackets and upper left molar brackets were mounted in the test apparatus and precisely defined torsional moments were applied using a 0.018 × 0.025 (nominal) stainless steel wire. At the same time the amount of twist of this wire was recorded. From the twist-moment diagrams it was possible to determine when the brackets started to deform permanently or open up completely.

The Investigations

Analysis of Slot Precision

The material used in the study (Table 4-1) comprised five different types of lingual bracket from four manufacturers. All these brackets are made of stainless steel and are produced with metal injection molding (MIM) technology except for the STb bracket (Figs 4-5a and 4-5b), which is a milled bracket. The Conceal II (Figs 4-6a and 4-6b) and the 3D bracket

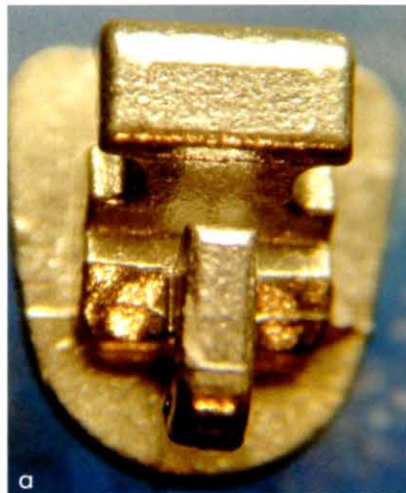
Table 4-1 Brackets used in investigation of slot precision (at least 10 of each type of bracket/tooth).

Manufacturer	Bracket	Slot dimension
Creekmore Enterprises	Conceal II	0.016
Dentaureum	Magic	0.020
Forestadent	3D Bracket	0.016
ORMCO	Kurz 7th Generation	0.018
ORMCO	STb	0.018

Figs 4-5a,b STb bracket 1st generation (ORMCO, USA). Horizontal slot.



Figs 4-6a,b Conceal II bracket (Creekmore, USA). Vertical slot.

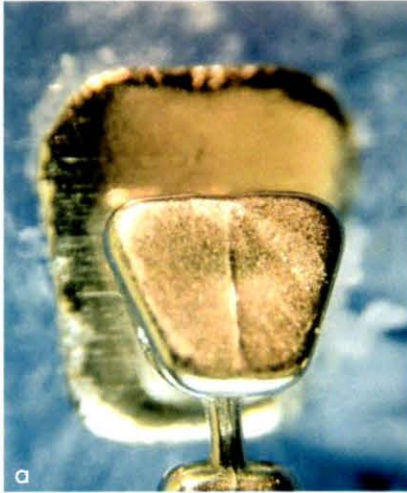


Figs 4-7a,b 3D bracket (Forestadent, Germany). Vertical slot.



(Figs 4-7a and 4-7b) have a nominal slot size of 0.016, the ORMCO 7th generation brackets used in this investigation (Figs 4-8a and 4-8b) and the STb brackets (see Figs 4-5a and 4-5b) have a nominal slot size of 0.018, and the Magic bracket (Figs 4-9a and 4-9b) has the largest slot size of 0.020.

The brackets were divided into groups of upper central, upper lateral, upper canine, lower incisor, lower canine, premolar, and molar with 10 brackets in each group. The brackets were measured with the help of high precision end gauges (Fig. 4-10; Azurée Jauges SA, Moutier, Switzerland).



Figs 4-8a,b 7th Generation brackets (ORMCO, USA). Horizontal slot.



Figs 4-9a,b Magic brackets (Dentaurum, Germany). Horizontal slot.



Fig. 4-10 End gauges in 0.002 mm steps.

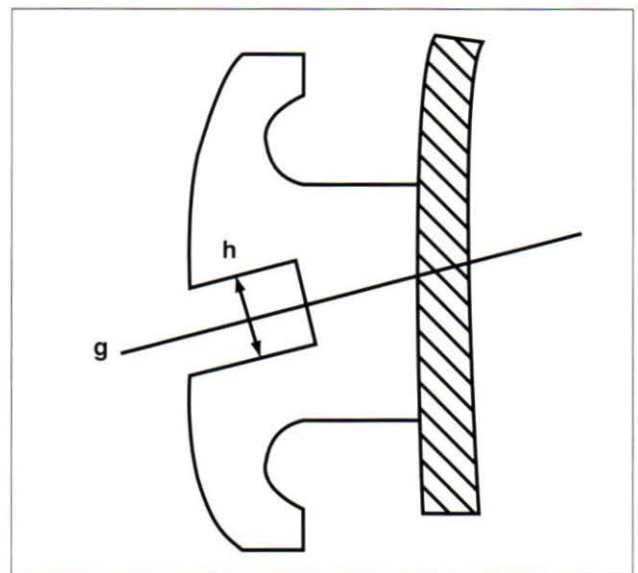


Fig. 4-11 Measurement of slot height according to ADA specification 100.

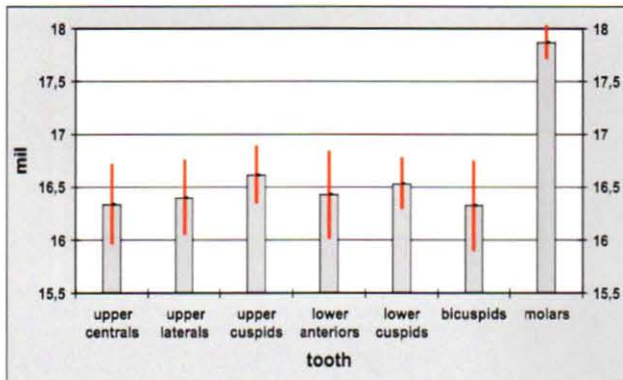


Fig. 4-12 Slot measurements for Conceal II brackets (Creekmore, USA). mil = 1/1000 of an inch.

The brackets were held manually and the gauge pin was inserted like an archwire into the slot with an insertion force less than 2 N. The gauges were used in steps of 0.002 mm (2 μ m) and the measurements were made under 2.5-fold magnification. Visual checks of the bracket slots were performed under the light microscope and photos were taken at $\times 20$ and $\times 40$ magnification. This allowed us to evaluate the surface roughness and any flush in the slots that might prevent the archwire from reaching the bottom of the slot or prevent it from entering the slot at all. Slot height was measured as the smallest dimension of the slot between the slot walls at one-half of the slot depth (Fig. 4-11) according to the American Dental Association (ADA) Specification 100 (2005) (also see: DIN 13971-2).

Figure 4-12 shows the mean slot sizes and standard deviation for Conceal brackets for all tooth types. In 37% of brackets it was not possible to insert the smallest gauge (0.0159) into the slot except from the mesial or distal aspect – as in a tube. This can cause problems for the clinician in the finishing phase, when slot-filling archwires of large dimensions are necessary to achieve perfect labio-lingual inclination. On the other hand, the measured size of the slots of the molar brackets considerably exceeded the nominal slot size of 0.016 – the average molar slot size was 0.0179. Thus precise torque control for the molars is not possible as the play between the largest wire that can be inserted into the brackets of the anterior teeth and the buccal tubes is much too large.

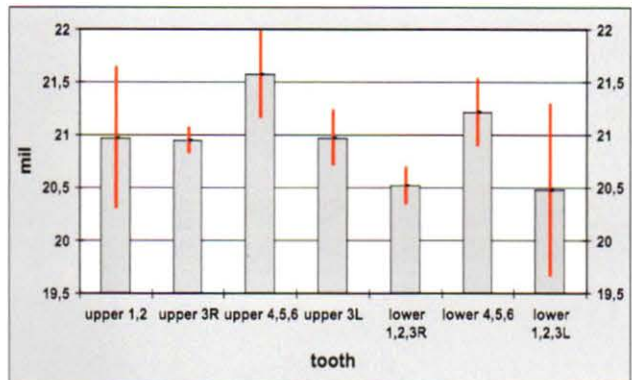


Fig. 4-13 Slot measurements for Magic brackets (Dentaurum, Germany).

As seen in Fig. 4-13, the values for the Magic bracket for the different teeth varied considerably – the standard deviation was largest for the lower incisor brackets on the left side. The difference between the smallest and the largest slot size was 0.124 mm or 24.8% of the nominal slot size. This was the biggest difference among all the brackets included in this study.

The Forestadent 3D bracket system has only two kinds of bracket. For the six upper and lower anteriors, brackets with 45 degrees difference between the occlusal plane and the wire plane are available. For premolars and molars 0 degrees torque is built into the brackets. Measurements were carried out with the clips open and no attempt was made to close the clips over the archwire. There is a tendency for a slightly oversized slot in the posterior brackets in comparison to the anterior teeth, but the standard deviation is low for both groups of brackets (Fig. 4-14). On average, the bracket slot for the anterior teeth is 0.015 mm (0.006") larger than the nominal slot and for the posterior teeth it is 0.023 mm (0.009"). This might be done on purpose by the manufacturer to allow for easier wire insertion in the brackets bonded to the posterior teeth.

The graph for ORMCO's 7th Generation brackets (Fig. 4-15) shows that none of the brackets had undersized slots. There was a remarkable difference between the lower right and left canines. The standard deviation for brackets of each tooth type was small.

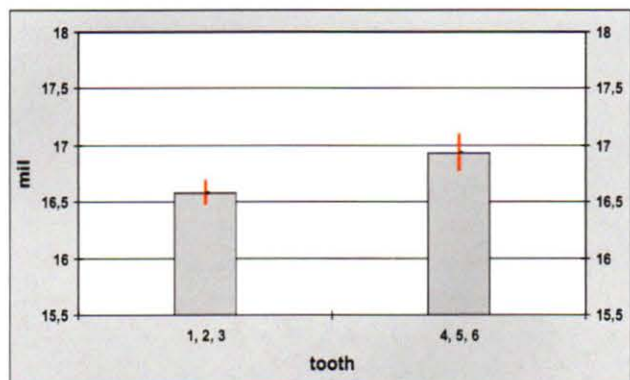


Fig. 4-14 Slot measurements for 3D brackets (Forestadent, Germany).

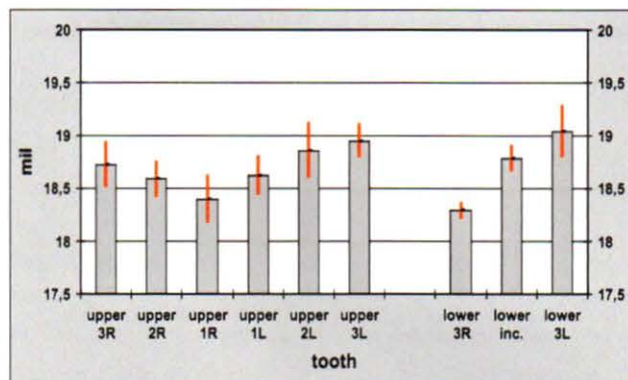


Fig. 4-15 Slot measurements for 7th Generation brackets (ORMCO, USA).

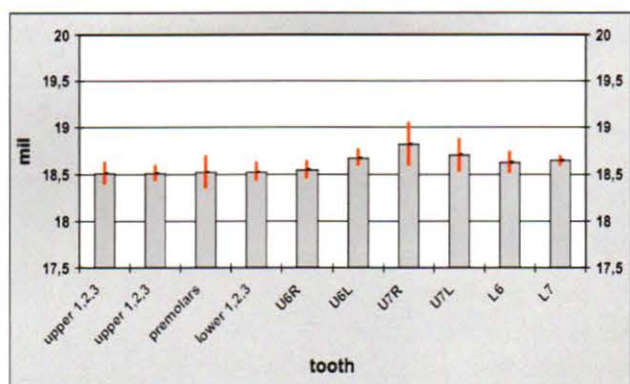


Fig. 4-16 Slot measurements for STb brackets (ORMCO, USA).

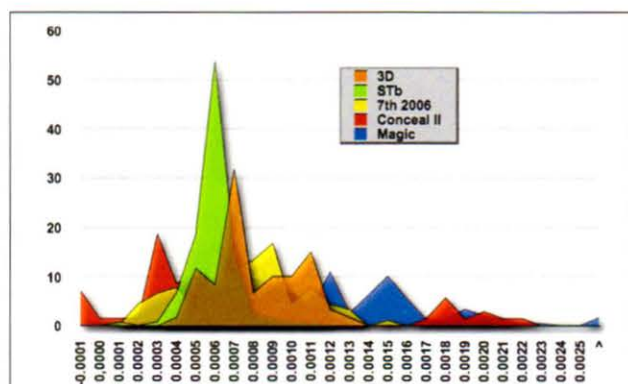


Fig. 4-17 Comparison of all brackets: relative distribution of the measured values around the nominal slot dimension (nominal slot dimension is zero on the x-axis).

The STb brackets were found to have the most consistent bracket slot sizes (Fig. 4-16). Each group of brackets showed a very small standard deviation and only minor differences in slot size which can probably be explained by the fact that the STb brackets are milled. There is a very slight tendency for larger slot sizes in the posterior teeth. The STb brackets used in this study were the first generation of STb brackets manufactured in Japan. The second and the third generation, which differ from the first mainly in a different base design (mesh base), showed similar results.

For easier comparison, Fig. 4-17 shows different relative distributions of the measured values in relation to the nominal slot size. The STb bracket

clearly displays the narrowest distribution around the designed slot size (0.0185) whereas the values for some of the investigated brackets are quite spread out.

In general it can be stated that there are large differences between the brackets both with regard to the average slot size and the variations between the different types of teeth.

In a number of brackets (37% of the Conceal II brackets) access to the slot was limited at the slot entry by flush material ("press-stud effect"), in some brackets this merely limited the maximum size of wire that could be inserted whereas in others, the insertion was made impossible. It was only possible to measure the slots of these brackets by inserting the

gauge sideways into the slot like a tube. However, this is not acceptable clinically. There were problems regarding the slot size of Conceal II (Creekmore) and the Magic (Dentaurum) brackets.

The STb brackets (ORMCO) had the most precise slot size in this investigation. Manufacturers should focus on the precision of the tools used to produce the brackets and should integrate into their production process a tight quality control system that will reveal any aberrations before the brackets are distributed for sale. This means that the nominal slot size should neither be significantly exceeded nor undersized. Also, any flush material that might impede the insertion of the archwire into the slot is unacceptable. If not detected by the clinician, this might lead to undesired tooth position.

Torsional Stability

We studied the torsional stability of six types of lingual bracket (Table 4-2). The design of all these brackets is quite different. The ORMCO (7th generation and STb brackets) and American Orthodontics (Stealth) brackets have a horizontal slot and the archwire is inserted parallel to the occlusal plane. The Adenta Evolution bracket is designed for insertion of the archwire perpendicular to the occlusal plane, ie, from occlusally. The Adenta bracket retains the wire in the slot using a spring-loaded lock, and is therefore referred to as a "self-ligating" bracket by the manufacturer. The TOP Service Incognito bracket (Wiechmann 2002) is unique in that the direction of

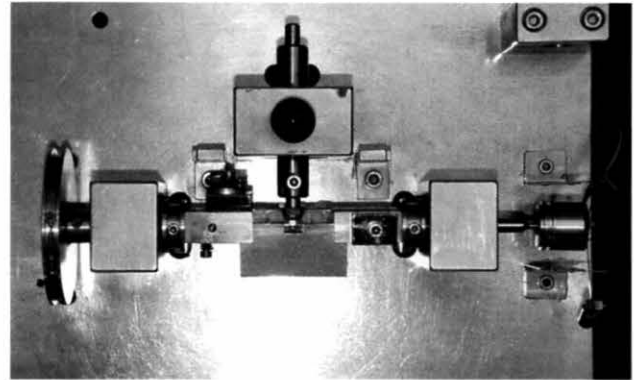


Fig. 4-18 The test apparatus.

insertion can be selected by the orthodontist prior to manufacture. Both occlusal insertion and horizontal insertion are possible. The Magic bracket has a combination of vertical and horizontal slots in the incisor brackets and a vertical slot in the premolar and molar brackets. All lingual brackets are made from stainless steel except for the Incognito bracket, which is a gold alloy casted bracket manufactured in a rapid prototyping process. For the analysis of torque strength, 10 upper right central incisor brackets and 10 upper left first molars brackets were used for each type.

To measure the torque strength of the brackets, they were mounted in an apparatus (Fig. 4-18) developed by Ødegaard and co-workers (1993) and modified by the authors. The brackets were mounted in such a way that the slot was horizontal and coinciding with the rotational axis of the instrument. Depending on the bracket type, the

Table 4-2 Brackets used in investigation of torque stability and some of their characteristics.

	Manufacturer	Name	Alloy	Slot length (mm)	
				Incisor	Molar
A	ORMCO	Kurz 7th Generation	17-4PH	2.54	3.86
B	American Orthodontics	Stealth	AISI 450	2.12	3.42
C	TOP Service	Incognito	Degulor M	2.85	2.85
D	Adenta	Evolution	Not known	2.36	2.57
E	Dentaurum	Magic	Not known	2.80	3.18
F	ORMCO	STb	17-4PH	2.50	3.00

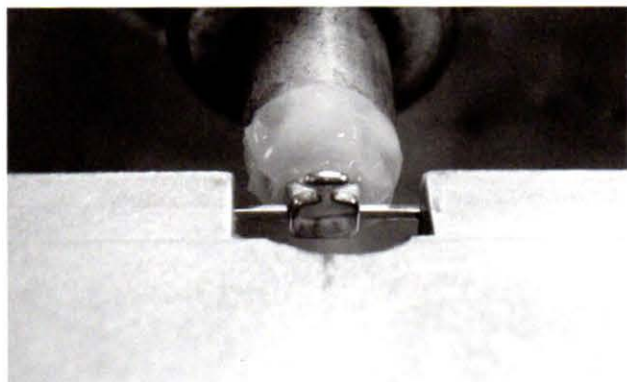


Fig. 4-19 Test bracket on a 0.018 × 0.025 wire.

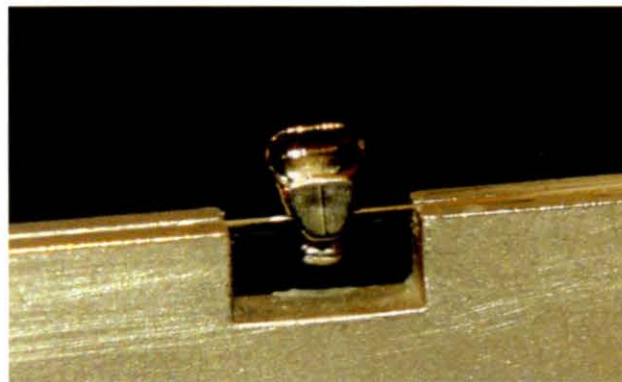


Fig. 4-20 The wire holder.

support had to be adapted from being horizontal for the Incognito incisor brackets to over around 45 degrees to the horizontal for the ORMCO 7th Generation incisor brackets to vertical for the molar brackets. Both the brackets and the mounting base were micro-sandblasted (DentoPrep, Rønvig A/S, Daugård, Denmark) to enhance bond strength. For the test pieces supplied by TOP Service, a metal primer (Reliance Orthodontic Products, Itasca, IL, USA) was used on the base after micro-sandblasting. The test brackets were mounted using light curing bonding material (QuickCure, Reliance Orthodontic Products, Itasca, IL, USA).

The instrument was modified to record the twist of the wire electronically. The twist was measured using an angular sensor MP 1545 (Megatron Bauelemente, Putzbrunn/Munich) on the axis of the test wires. The MP 1545 is an inductive sensor that requires less than 1 Nmm moment to turn. The output was registered using a digital voltmeter. The discrimination of this set-up was about 0.1 degrees. The torsional moment to test the brackets was created by twisting an 0.018 × 0.025 stainless steel wire (Nubryte Gold, GAC International, Islip, NY, USA) in the slot of the test bracket (Fig. 4-19). A new piece of wire was used for every test.

The moment itself was created using weights and a pulley of 65 mm diameter and could therefore be calculated as:

$$\text{moment (in gmm)} = \text{applied weight (in g)} \times 65 \text{ mm}$$

The test wire was inserted in a holder (Fig. 4-20) that limited the free span to 8 mm. To measure the elasticity of the test wire itself without a test bracket and to determine the elastic limit of this wire five pieces of test wire were measured with the center of the wire being fixed in a small vise with a width of 4 mm.

For each measurement, the bracket was mounted and then the applied moment was increased in steps until either the slot opened up and the wire rotated in the slot or until a moment of about 120 Nmm was reached. Torsional moments were applied in the direction of lingual root torque (positive torque) for the incisors and buccal root torque (negative torque) for the molars as these were considered the most common directions in the systematic application of larger torque moments in a clinical situation. In cases of bond failure of the bracket, no measurements were possible and the total number of measurements made for that bracket type was fewer than 10.

Moment-twist curves were created from each measurement. In these the beginning of elastic deformation was determined by an interactive two-step procedure. In the first step, the curves were analyzed visually and an area of the curve that was clearly linear was determined. The slope of the curve in this area was calculated using least-squares approximation and the resulting regression line was overlaid on the graph. In the second step, it was determined at which point the measured curve started to deviate from the straight regression line. The moment at this point was defined as the end of linear elasticity. The measurements of the wire alone

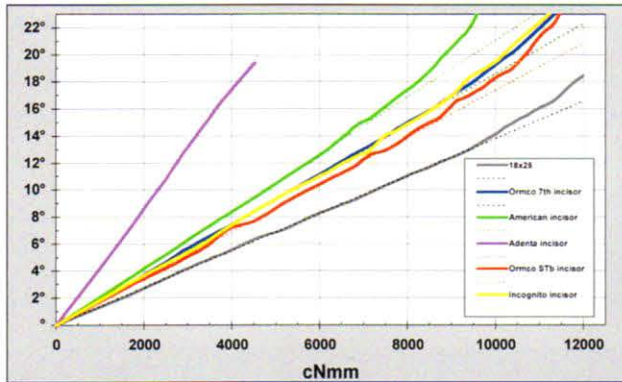


Fig. 4-21 Moment-twist curves for the incisor brackets.

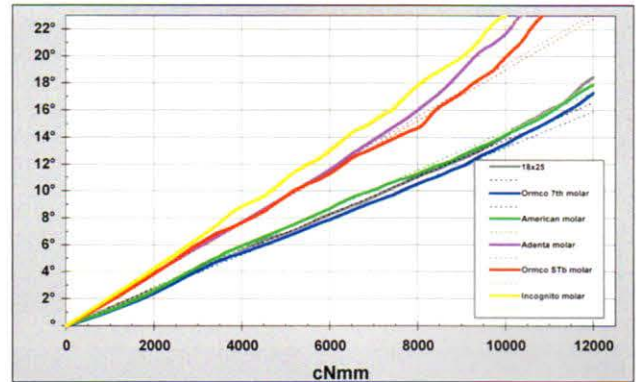


Fig. 4-22 Moment-twist curves for the molar brackets.

in the vise showed that the test wire used could sustain a torsional moment of 9411 gmm. Any measured moments larger than that could be either only wire deformation or a combination of wire and bracket deformation. Any deformations at moments smaller than 9411 gmm would be deformations of the bracket only.

Figures 4-21 and 4-22 show the moment-twist curves for all brackets tested:

- For the **ORMCO 7th generation** incisor and molar brackets, all 10 deflection curves were very consistent and no bracket deformation was detectable with this set-up.
- The **American Orthodontics Stealth** incisor bracket showed a lower yielding point; after the application of more than 6300 gmm the bracket slot opened and the bracket deformed. The molar bracket was more stable and measurable deformation took place only above 9600 gmm.
- The yield point for the **TOP Incognito** incisor brackets was detected at 8800 gmm, with very consistent curves. After some modifications of the bracket design since 2002 (which had a torque strength of 6800 gmm) the currently marketed molar brackets started to deform only after the application of more than 9200 gmm.
- **Dentaurum's Magic** incisor brackets were the only brackets with a 0.020 slot. The mounting rig was modified for this but even then it was not possible to measure the deformation due to oversized slot sizes. For the incisors there was around 16 degrees of play in the majority of test

brackets and for the molars the play was even larger (see Table 4-3). This led to an undesired movement of the wire out of the slot before deformation measurements were possible.

- The **STb** incisor brackets showed very harmonious curves with good resistance to deformation. Any bracket deformation that took place was after the application of a moment of more than 9500 gmm. The same was true for the STb molar brackets, which were tested after converting the molar tubes to brackets with an open slot.
- In the **Adenta Evolution** incisor brackets, torque is not applied through the walls of the bracket slot but through the elasticity of a spring clip. The clip opened completely and released the wire at the application of between 4300 and 7800 gmm but the integrity of the bracket body was not compromised. To achieve 2000 gmm of torsional moment, the wire needed 5 degrees of twist more than in the other brackets in which the slot walls transmit the torque. The **Adenta** molar brackets consist of a twin bracket body and a rather small base in comparison with the other molar brackets. The bracket body was capable of sustaining moments of up to 6000 gmm. Nevertheless, in the test setup the torquing wire was kept in the test brackets by the apparatus. Therefore it could not be determined whether the clip was able to achieve this. All the 10 test brackets debonded at the bracket-composite interface before deformation took place. This may be due to the surprisingly few undercuts in the bracket base.

Table 4-3 Calculated play for given archwire–bracket combinations.

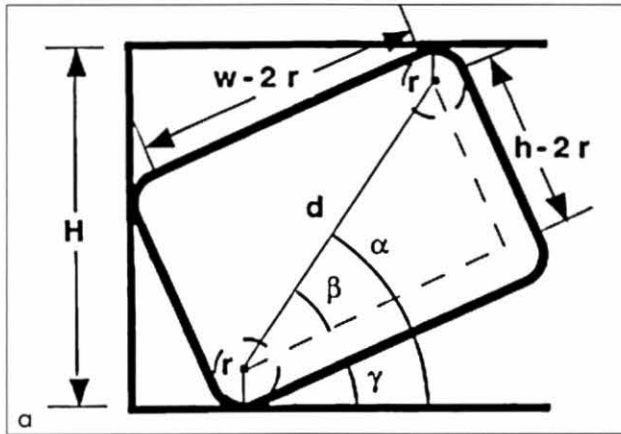
Bracket	Narrowest slot measured	Widest slot measured	Difference
Conceal II (0.016 slot)	0.396 mm	0.460 mm	0.064 mm
Calculated play:			
0.016 × 0.016 wire	Wire could not be inserted	11.25 degrees play	11.25 degrees
0.016 × 0.022 wire	Wire could not be inserted	7.02 degrees play	7.02 degrees
Magic (0.020 slot)	0.508 mm	0.632 mm	0.124 mm
Calculated play:			
0.019 × 0.019 wire	3.96 degrees play	34.86 degrees play	3.90 degrees
0.020 × 0.020 wire	Wire could not be inserted	22.54 degrees play	22.54 degrees
3D bracket (0.016 slot)	0.416 mm	0.438 mm	0.022 mm
Calculated play:			
0.016 × 0.016 wire	1.83 degrees play	6.30 degrees play	4.47 degrees
0.016 × 0.022 wire	1.21 degrees play	4.06 degrees play	2.85 degrees
7th Generation (0.018 slot)	0.460 mm	0.494 mm	0.034 mm
Calculated play:			
0.016 × 0.022 wire	7.02 degrees play	11.88 degrees play	4.86 degrees
0.018 × 0.025 wire	0.30 degrees play	4.05 degrees play	4.02 degrees
STb bracket (0.018 slot)	0.458 mm	0.474 mm	0.016 mm
Calculated play:			
0.016 × 0.022 wire	6.75 degrees play	8.98 degrees play	2.23 degrees
0.018 × 0.025 wire	0.09 degrees play	1.82 degrees play	1.73 degrees

Discussion

The precise transfer of forces, and especially torque, is of utmost interest to the clinician and the patient. Inaccurate bracket slots and large variations between brackets on different teeth must lead to unacceptable and compromised treatment results because of the reasons described above, or at the very least make life for the orthodontist much more difficult because of the complicated torsional bends that are required to be added to the archwire after the problem becomes apparent. Calculation of play of the archwire (see equation in Fig. 4-23) according to Meling and co-workers (1998) in the measured bracket slots brings up distinct differences

between the brackets tested. Obviously the larger the play for a given archwire, the less precise is the bracket system and the more the difficulties that may arise while trying to achieve the perfect tooth position. It might still be possible to achieve a good result but it would require addition of third-order correction bends and much more time and effort.

If a lingual bracket of a nominal size of 0.018 is bonded on the palatal surface of an upper central incisor and a 0.018 × 0.025 slot-filling archwire inserted, we would expect a very small play of the archwire and therefore a very precise torque transfer and a very perfect tooth position at the end of treatment. For the STb bracket, the amount of play for this bracket–wire combination was 0.09 degrees for the narrowest slot



$$d = \sqrt{(w - 2r)^2 + (h - 2r)^2}$$

$$\gamma = \arcsin \frac{H - 2r}{d} - \arcsin \frac{H - 2r}{d}$$

Fig. 4-23a,b Formula for the calculation of play in a given archwire-bracket combination.

measured and 1.82 degrees for the widest slot. The maximum difference between the play from one to the other bracket is just 1.73 degrees which represents very good value in the clinical application.

When conducting the same experiment with a Magic bracket that comes with a nominal slot size of 0.020 it was necessary to insert a 0.020 × 0.020 archwire for perfect torque control. The narrowest bracket slot measured for this bracket did not allow this wire to be inserted, while the largest showed 22.54 degrees of play. That means a difference between the brackets for all teeth of 22.54 degrees. Obviously this can result in different torque values for different teeth, and differences from 3 degrees onward are visible even to lay persons, especially in the case of differing torque of the two central incisors. A smaller archwire, for example a 0.019 × 0.019 wire, inserted into the Magic brackets led to moderate play in the narrowest bracket (3.96 degrees) but the wire had a calculated play of nearly 35 degrees in the largest measured bracket slot and thus did not allow any torque control.

These results show how important a precise bracket slot size is, especially in lingual orthodontics, where small torque errors can result in a large vertical positioning error of the teeth. This is also the reason why the fit of the orthodontic archwire in the slot needs to be as precise as possible. A tolerable amount of play between a slot-filling archwire and the slot should be considerably less than 5 degrees

to transfer the desired tooth position from the set-up to the intraoral situation without having to make time-consuming corrective bends.

We found differences between brackets from different manufacturers and also within brackets from a single manufacturer, and our results showed that the values for STb brackets are at the upper end of the precision and can therefore be recommended for clinical use.

When deciding on the ideal bracket for lingual treatment, the orthodontist requires that there will be correct transmission of the torque value built into the bracket, or bent into the wire, to the teeth with:

- no unplanned deformation of the bracket
- no unplanned deformation of the wire
- easy insertion and ligation.

The unplanned deformation (Frohmann 1996) of the bracket does not seem to be a problem with the brackets surveyed in the present study with the exception of the Adenta Evolution bracket. Here it has to be decided whether the opening of the clip during the application of torsional moments is planned and desirable. If the opening of the clip is intended, the operator must make sure that sufficient extra torque is bent into the wire or built into the bracket so that a meaningful torque control is present. Clinical trials are required to show whether this will be possible.

An unplanned deformation of the archwire does not seem likely as we found that a 0.018 × 0.025

stainless steel wire is capable of exerting a torsional torque moment of more than 9000 gmm, which is about three times as much as would be needed clinically.

Conclusion

Several factors influence precise torque application:

- the slot geometry (parallel walls)
- the wire dimensions
- the edge bevel (also varies)
- the slot dimension (relation between largest wire used and actual slot dimension)
- a bracket design that is strong enough to withstand torsional moments
- ligation that is capable to hold the wire fully in the slot.

The results of the investigations described in this chapter show that torsional stability seems to be less of a problem than manufacturing brackets with precise slot dimensions.

Slot precision has been neglected somewhat in the past. However, as slot precision is extremely important for the final result in patients requiring torque control or the application of torque, and considering the high cost of lingual brackets, the orthodontist should demand brackets with excellent slot precision.

High intra-sample variation will lead to low reproducibility, and inter-manufacturer deviations should also be minimal, as clinicians may work with brackets from one manufacturer and wires from another manufacturer. It may be beneficial to use a system where the same bracket type is used for all anterior teeth because this will minimize the inter-tooth variation in the slots. Our results indicate that the STb bracket system is a very precise appliance and it can therefore be recommended for clinical use. Further studies are necessary to check the precision and reproducibility of lingual brackets being produced currently. Some manufacturers may need to reconsider their production processes.

The results of the torsional strength test were within the desirable range of stability and were also

highly comparable with conventional labial twin metal brackets. For example, the deformation for a metal bracket like GAC Omniarch starts beyond 9400 gmm and for the Forestadent Minimono "N" around 9100 gmm. All these values are well above the clinically required or sensible moments when it comes to the transfer of torquing moments from brackets to teeth.

Ceramic brackets tested with the same method show slightly less torque stability. For example, the 3M Unitek ceramic bracket Clarity can stand forces up to 6000 gmm before fracture occurs. In a ceramic bracket, the failure is more apparent because the bracket fractures and is no longer usable. With metal brackets, both labial and lingual, excessive torsional moments lead to an opening of the slot rather than catastrophic failure. An uncontrolled enlarged slot, though, is detrimental to efficient treatment as has been explained above.

The method used in our study resembles the clinical situation as closely as possible. Alternative tests involve a lever arm, like Flores and co-workers (1994) used, where there are problems with the effective length of the lever. And the use of different archwire sizes might lead to different results for comparison.

Our clinical requirements to torque the upper centrals are certainly below 2500 gmm, and molars might receive torques of up to 3500 gmm. It can be stated that all the brackets we tested survived these loads. Clinical problems might arise during ligation and removing of archwire – that is when the ceramic brackets fracture.

In the Adenta bracket the clip retention led to an increased "play" even with a 0.018 × 0.025 wire. There was a recognizable influence of direction of the torquing moment. The Adenta bracket showed different stability depending on the direction of the moment.

All the tested brackets are capable of sustaining the clinically required moments. In the clinical situation, the wire will deform before the bracket slot opens up; only in the Adenta bracket will the clip open earlier.

Precise torque application is only possible with archwires that fill the slot: an 0.018 slot requires

an archwire that is at least 0.018×0.025 . The Dentaureum 0.020×0.020 archwire showed 22.5 degrees of play in the 0.020 slot.

In summary, it can be said that perfect torque transfer is dependent on a precise slot and wire dimensions. On the one hand, our study showed that this is not always the case, especially with the Magic brackets (Dentaureum): the oversized slots increase the play of the archwire in the slot and make precise delivery of torque to the bracket

impossible. The spring clip in the Adenta bracket opens up and allows the archwire to leave the rather shallow slot walls. This mechanism leaves the question open whether it is possible to transfer clinically useful amounts of torque with these brackets. On the other hand, the study showed that it is possible to produce high precision slots that are strong enough for clinically required torsional moments, for example the STb and the Incognito brackets.

5 LIGHT WIRE LINGUAL ORTHODONTICS: BIOMECHANICAL CONSIDERATIONS

Dietmar Segner & Dagmar Ibe

Introduction

In orthodontic treatment, the archwire is probably the most important component of the appliance. The elasticity of the archwire moves the teeth during leveling, torquing, and finishing stages of treatment. During the other stages of orthodontic treatment, the archwire works as a guiding track, along which the teeth are moved by the forces generated by coil springs or elastic chains. In this mode the archwire is intended to make sure that undesired movements of the teeth are avoided.

Wire Cross-section and Wire Stiffness

When the biomechanical effect of an archwire is discussed, two characteristics are of major importance: the wire cross-section in relation to the slot and the wire stiffness. Until recently these two characteristics were strongly correlated as the classic stainless steel wires adhered to Hooke's law, which dictates that the stiffness is correlated to the fourth power of the diameter. A thicker wire therefore not only reduces the play between the archwire and the bracket slot but also increases the stiffness severely.

The direct relationship between cross-section and wire stiffness was challenged first by the development of multistranded wires such as Twistflex®, Respond®, or Coaxial®. In these wires, the sum of the stiffness of the individual strands is much lower than the bending stiffness of a single-strand wire of the same diameter. However, problems with the bendability and form stability led to the development of archwires made of materials other than

steel. With the use of titanium, the wire stiffness was reduced by about one-half. Later, the use of nickel-titanium (NiTi) further reduced the stiffness of archwires of the same cross-section to about one-sixth of that of steel. As a result, it was possible to select wire stiffness and wire dimension somewhat separately. However, the fact that the cross-section influences stiffness by the power of four still did not allow complete freedom in the separate choices of stiffness and wire dimension. As an example, a 0.017×0.025 archwire would have almost 12 times the stiffness of a 0.014 round archwire in the horizontal direction and 5.5 times the stiffness in the vertical direction. Especially in the lingual technique, an additional problem is the small inter-bracket distance (Moran 1987). Even with narrow brackets the reduced inter-bracket distance will lead to increased forces as the length of the elastic span to the third power is inversely related to the exerted force. For that reason the newer lingual bracket systems generally have narrower brackets (Fuek et al 2005).

Factors Affecting the Magnitude of the Generated Force

The development of superelastic archwires was supposed to solve the problems described in the previous section, and, indeed, led to great advances in the lingual technique. However, studies have proved that not all superelastic archwires have the desirable properties and force levels (Segner and Ibe 1995). Wires with identical dimensions have shown grossly different force levels on the superelastic plateau. Nevertheless, superelasticity with a suitable force level on the deactivation plateau has some promis-

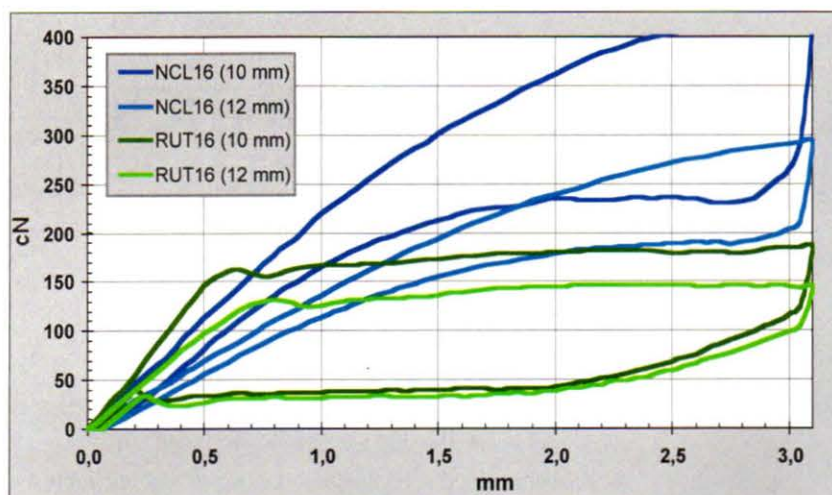


Fig. 5-1 Influence of different wire spans (inter-bracket distances) on force level of 2 different nickel-titanium archwires. One material (NCL) shows strong dependency of force level and wire span. The other material (RUT) is a superelastic material and shows almost no effect of the wire span on the force level.

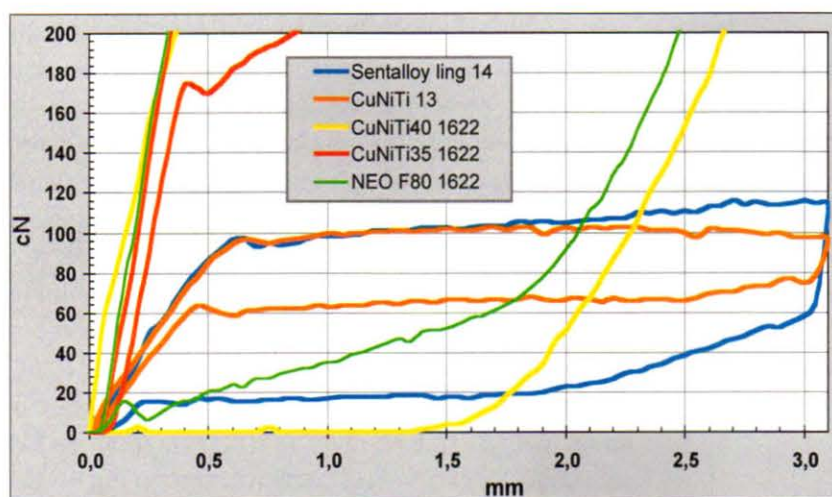


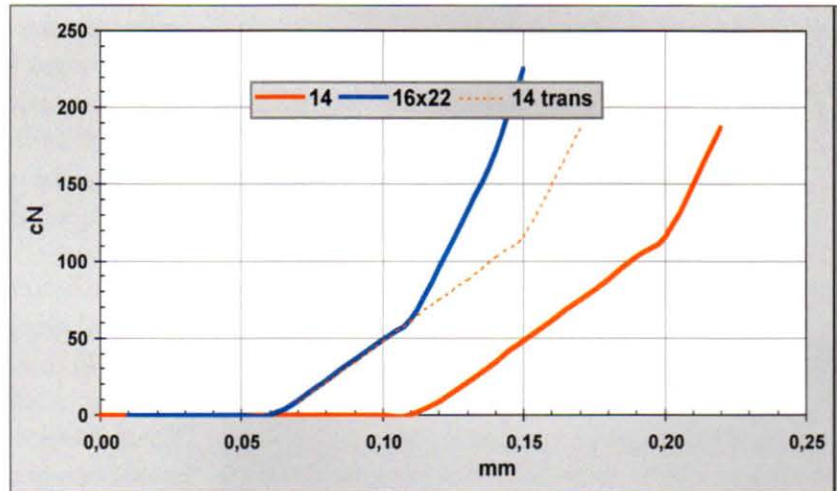
Fig. 5-2 Force-deflection diagram for some typical leveling wires used in lingual orthodontics: 0.014 Sentalloy lingual and 0.016 × 0.022 NEO-Sentalloy F80 (both by GAC, USA); 0.013 copper-NiTi, 0.016 × 0.022 35°C copper-NiTi, and 0.016 × 0.022 40°C copper-NiTi (all by ORMCO, USA). Measurements were taken using a three-point bending test according to ISO 15841/ADA Spec 32. Note the initial force peak for the wires with a rectangular cross-section.

ing advantages. Because of the almost constant force on the plateau, even severely malpositioned teeth do not receive much higher forces than moderately irregular teeth. Of special interest in lingual orthodontics is the fact that inter-bracket distance is not important any more (Segner 1995). As can be seen in Fig. 5-1, the forces generated by a truly superelastic archwire (RUT in Fig. 5-1) are almost completely independent of the span of the wire or inter-bracket distance.

In addition, it is possible to design the forces produced by superelastic nickel-titanium wires independent of the wire cross-section during the manufacturing process. So at first glance it seems that the problem of force generation in lingual orthodontics is solved, and that all patients could

benefit from low and constant forces. When measuring the forces of some wires commonly used in lingual orthodontics, though, it becomes clear that the situation is much more complex. In Fig. 5-2, forces developed by the wires have been plotted against the mechanical deformation of the wire. Of interest are the deactivation curves. It is quite apparent that very large differences exist between the different wire materials. In the case of round wires, the 13 round copper-NiTi generates about three times more force than the thicker 14 round Sentalloy wire. In the case of rectangular wires, we have the situation that the 35°C Copper-NiTi archwire in a 0.016 × 0.022 generates so much force that it is hardly shown in the diagram (more than 200 cN), and it is questionable whether it

Fig. 5-3 Force–deflection diagram of two wires of identical bending stiffness ($E \cdot I$) and different cross-sections. The wire material for the red curve was assumed to have the E-modulus of steel (201,000) while the thicker wire for the blue curve was assumed to have an E-module of only 50 473. Traditional elasticity theory and measurements in a three-point bending test gave identical results for the two wires. When measured in a three-bracket set-up, though, it shows that the wire with the larger cross-section not only had less vertical clearance, but even after the clearance was used up, the thinner wire displayed a slower increase in the force level with increasing activations, as can be clearly seen in the dotted red curve, which is a transposed copy of the red curve. Assumed dimensions: bracket slot height 0.0185, slot length 2 mm, inter-bracket distance 3 mm.



$$s = \frac{(F - F_{B_{\max}}) \cdot l^3}{12 \cdot E \cdot I} \times \frac{\left[\frac{1}{2} + \frac{5b}{3l} + \left(\frac{b}{l} \right)^2 \right]}{1 + \frac{5b}{6l}}$$

would be suitable as a leveling wire. The NEO-Sentalloy wire delivers low forces at the end of deactivation (20 to 60 cN), but for the first millimeter of deactivation the forces generated are up to 300 cN (initial force peak). The Copper-NiTi 40°C archwire in 0.016 × 0.022 has an initial force peak of more than 250 cN after which the force dissipates completely.

It is clear that the rectangular archwires are far from ideal with regard to delivery of constant and moderate forces. With round wires of thin diameter it is possible to have very small and relatively constant forces if the right wire material is chosen. Until now the force designed into a wire material is not completely independent of wire dimension. This is obviously also true for all classic linear materials such as stainless steel, titanium, and non-superelastic nickel-titanium.

In addition, the tighter fit between the archwire and the bracket slot in the case of the thicker wires would lead to more severe deformation and therefore even higher apparent stiffness in the limited inter-bracket span. A study by Ødegaard and co-workers (1995) showed that the stiffness of archwires in a three-bracket set-up can be evaluated by:

where s is the deflection resulting from a force of F (l represents the inter-bracket distance, b the width of the bracket, E the modulus of elasticity, and I the polar moment of inertia). The product $E \cdot I$ is a measure of the wire stiffness. It can be shown both by employing the formula and also empirically that two archwires with the same stiffness will exert a different force in a given situation. The wire with the larger cross-section will show a significantly higher force level although the stiffness is the same. The force–deflection diagram in Fig. 5-3, comparing two hypothetical wires of different dimension but identical stiffness ($E \cdot I$), clarifies these dependencies. The bracket slot sizes and inter-bracket distances were equal. The figure clearly shows that the hypothetical 16 × 22 wire exerts much higher forces than the 14 round wire although both have the same stiffness. Therefore archwires of a smaller cross-section with some play between the wire and the bracket slot wall not only have lower stiffness, but they will also generate lower forces more slowly.

The stiffness of a wire is relevant for active movements of teeth or for the control in all three planes of space as well as control of rotations and tip during movement of teeth along the archwire. The

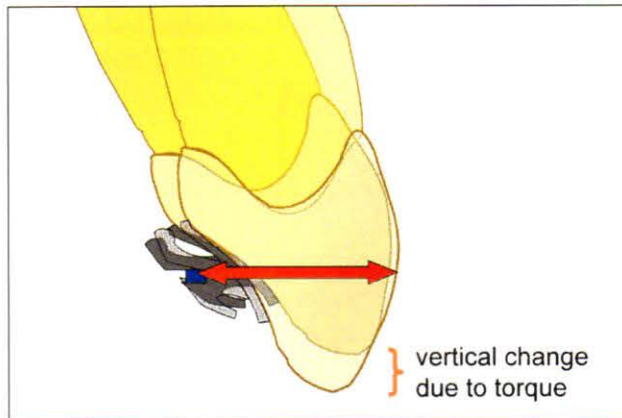


Fig. 5-4 Relationship between inclination of a tooth and the apparent vertical length of that tooth. While the vertical position of the *bracket slot* remains unchanged, the position of the *incisal edge* may change with the axial inclination. This can happen when the axial inclination is actively or inadvertently modified. Although the vertical problem could be solved with a vertical step, this would not correct the inclination error. To correct the inclination either a perfect fit between archwire and slot, in combination with a good set-up, is necessary, or, alternatively, a corrective third-order bend should be made in the archwire. The red arrow indicates the horizontal distance between bracket slot and labial surface of the tooth.

cross-section of an archwire, or more precisely the cross-section in relation to the slot geometry, determines whether an archwire can produce moments to control the buccolingual and mesiodistal inclination of the teeth. As described in the previous chapter, precise torque application requires very tight tolerances in both the bracket slot and the archwire dimensions to achieve the correct torque inclination. Even a play of only one-hundredth of a millimeter can result in a torque error of a few degrees.

Factors Affecting Torque Control

In lingual orthodontics third-order control is even more important than in labial orthodontics. The reason is the relationship between the vertical position of the incisal edges or the buccal cusps and the torque angulation. Figure 5-4 clearly shows that the incisal edge moves downward when the tooth is allowed to rotate around the archwire towards a more retroclined position

although the bracket and the archwire are still in the same vertical position. This effect is much more pronounced in lingual orthodontics because the horizontal distance between the labial surface and bracket slot is much larger than in the labial technique (Fig. 5-4).

Indeed, this effect is responsible for many problems with, and, as a result, requires many expensive techniques in lingual treatments. It is one of the main reasons why most orthodontists use some form or another of a Custom Lingual Appliance Setup Service (CLASS) set-up, in which each tooth is positioned in its desired axial inclination and then the bracket is placed on the tooth with an individual bonding pad or by using a prototyping technique so that the slots are all parallel to the occlusal surface. These brackets are then transferred to the patient's mouth in the correct position and with the correct inclination using an indirect bonding technique. In theory, it should be possible to insert a rectangular archwire into the patient's mouth and all teeth should align with the correct axial inclination and vertical positioning of the incisal edges or buccal cusps. Unfortunately a number of factors lead to persisting problems in the actual treatment:

- **Unknown slot dimension.** As of now, manufacturers only state a nominal dimension, i.e. 0.018, 0.020, or 0.022. These numbers suggest that the slots are actually, for example, 18/1000th of an inch or 0.4572 mm. Unfortunately this is not true and most bracket manufacturers produce slots considerably larger than the nominal dimensions suggest.
- **Inconsistency in slot dimension.** Obviously it would make sense that the brackets on different teeth would all have the same actual slot dimension, even if it differs from the stated nominal dimension. Thereby each bracket/tooth would at least experience the same play between archwire and slot. Unfortunately even this is not assured by some manufacturers. Our own measurements showed that, for example, ORMCO Kurz 7th generation brackets for the upper left central incisor had an average slot height of 0.0183 while the brackets for the upper right central incisor had a slot width of 0.0194.

- **Unknown differences between stated wire dimensions and actual wires.** Although the tolerances and consistencies of orthodontic wires are much better than those of the bracket slots, some unknowns remain. Usually wires are slightly smaller than the nominal dimension suggests. In addition there is a rounding of the wire corners called edge bevel. The amount of this severely influences torque play and is unknown to the orthodontist.
- Even if the exact slot dimensions and wire dimensions are known to the orthodontist it is still difficult to minimize the play. If the real slot dimensions are, for example, 0.475 mm (0.0187") the largest wire that could be used would have a nominal vertical dimension of 0.018, which would frequently mean an actual vertical dimension of 0.45466 (17.9) mm. Using the formulas given by Meling and co-workers (1998) this would result in a torsional play of more than 2.5 degrees towards each direction because there is no larger wire dimension commercially available that would fit this slot more tightly.

In summary, it can be said that the axial inclination of the teeth and the precision of torque transmission in lingual orthodontics is of greatest importance but was not so easy to achieve in the past owing to limitations in the available hardware.

This predicament can be addressed by two basically different solutions. The first is to increase the slot precision in the production process and make it "user-selectable", in order to fit the brackets to the existing wires. An example is the system of custom-manufactured lingual brackets using CAD/CAM as described by Wiechmann (2002, 2003). While this system improves the torque transmission, it involves an elaborate and costly laboratory process and expensive bracket materials (individually cast gold). To achieve the desired torque precision, wires have to be selected that minimize the slot play which again tends to increase the forces generated by the archwires as described above.

The second approach to the torque problem is to increase the slot play instead of decreasing it. To be able to do that it first has to be determined

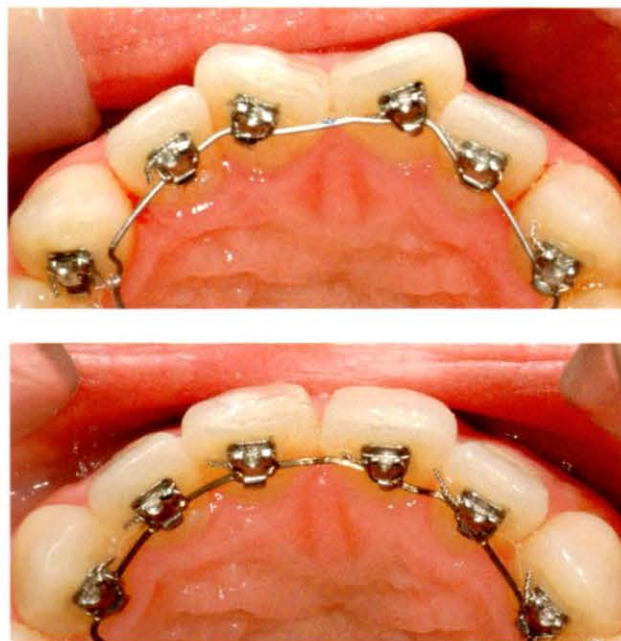


Fig. 5-5 Example showing leveling with just round wires in a non-extraction case. Note that the labial aspects of the incisors appear very similarly inclined.

whether active torque or torque control is necessary in a certain case. A number of patients undergoing a non-extraction treatment, whose teeth do not have problems with differing axial inclinations in the beginning, can be treated without the application of torque. A simple leveling case, as in Fig. 5-5, can be treated with round wires. If this approach is used a much more simple laboratory process can be used. Care needs to be taken, however, if torque is required in the later stages of treatment as then the problems described above would become pertinent.

Interestingly, it seems that treating such a patient with rectangular wires and without an optimal laboratory set-up in combination with perfectly precise slots and wires creates more problems than treating the same patient with round wires. Round wires cannot worsen the situation while rectangular wires can. Of course this is only true for patient cases that do not need torque. Most premolar extraction cases require the control of incisor torque to avoid retroclination of upper incisors and, of course, such patients cannot be treated with round wires alone.

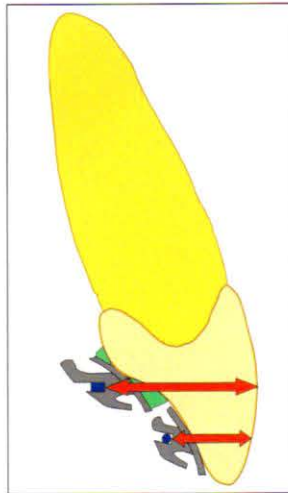


Fig. 5-6 Effect of vertical bracket position on bonding material thickness. The more gingivally positioned bracket has a thicker layer of bonding material under the bonding pad to achieve correct slot orientation. The more incisally positioned bracket has minimal bonding pad thickness and the slot is much closer to the labial surface, but at the cost of compromising slot orientation (torque).

Another factor that is of advantage in both the solutions described above is to have the slot bottom very close to the lingual enamel surface and on the incisors as far incisally as possible. As described above and in Fig. 5-4, vertical errors increase with increasing horizontal distance between slot bottom and labial surface. This distance is made up of:

- the distance between the slot bottom and bonding base
- thickness of the individual composite bonding pad
- the labiolingual thickness of the tooth.

To achieve a thinner bonding pad, it is of benefit to deviate from a perfect straight wire technique. Usually the canines are relatively more bulky towards the lingual. If a straight wire technique is desired, the bonding pads for the four incisors need to be of a certain thickness. By inserting first-order bends between lateral and canine this extra thickness can be avoided at the cost of extra bends. Another reason for thicker bonding pads is the necessity to achieve the correct torque for a bracket. If the manufacturer's bracket doesn't have the perfect torque built in, the bonding pad will be thicker either at the incisal side or the gingival side thereby increasing the bulk of the appliance and also moving the archwire away from the labial tooth surface. If the patient's treatment doesn't require torque, the

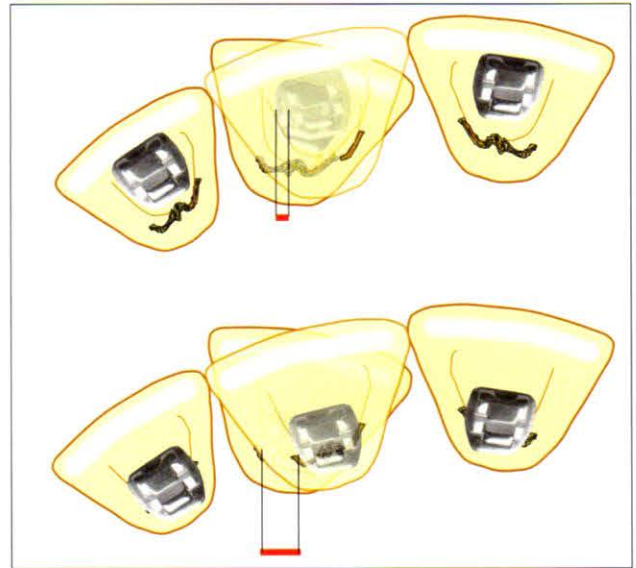


Fig. 5-7 Effect of vertical bracket position on derotation, illustrated by superimposing the rotated and derotated tooth (8)11. As the lingual bracket slot is moved further gingivally in relation to the contact point plane the slot has to move along the archwire during derotation (red line). The further the slot floor is gingivally, the larger is the contact area between the wire and the slot surface, as can be seen from the lower superimposition. Any friction between the archwire and the bracket or ligature will hinder the derotation.

brackets might be bonded maximally close to the lingual tooth surface which will increase the comfort and moves the archwire closer to the labial tooth surface. Another, but much more complicated and expensive, solution would be to individualize the bracket torque by customizing the bracket itself.

Bonding the bracket further incisally will bring it closer to the incisal edge where the tooth is thinner, and therefore, the archwire too will be closer to the labial surface (Fig. 5-6).

Having the archwire close to the labial surface, or more precisely close to the plane of the proximal contact points, offers another advantage with regard to derotation of teeth, as can be seen in Fig. 5-7. The further gingivally and thereby orally a bracket is positioned, and the thicker the base of the bracket and/or the bonding pad is, the more the slot has to move along the archwire and the greater will be the impact of friction.

Avoiding Archwire Binding

In lingual treatments the orthodontist is also confronted with a special form of binding between the archwire and the bracket slot. When a wire is curved within a confined bracket slot there will be a critical degree of curvature (curve radius) where the wire will come into contact on one side at the entrance of the slot and on the other side at the center of the slot wall (Fig. 5-8, top panel). Further increasing the tightness of the curve will create substantial pressure between the wire and the slot walls, especially with the classic linear wire materials.

The larger is the dimension of the wire in relation to the slot width, the more easy this binding will come about (Fig. 5-8, bottom). More play between archwire and slot will prevent it to a certain extent. The critical curve radius can be calculated as a function of slot width, slot length, and wire dimension (Fig. 5-9). In the figure it can be seen that the curve radius can be much tighter with wire dimensions of 0.014 or smaller; 0.017 or 0.018 archwires will lead to binding in most instances, so deformation during insertion binding is highly likely. Even with narrow brackets, an 0.016 round wire might experience binding if the irregularities in the dentition lead to deformations that require curve radii of smaller than 4.5 mm.

To get an idea of curve radii in a clinical setting, Fig. 5-10 shows the upper anterior teeth of a patient with irregularities and the corresponding curve radii.

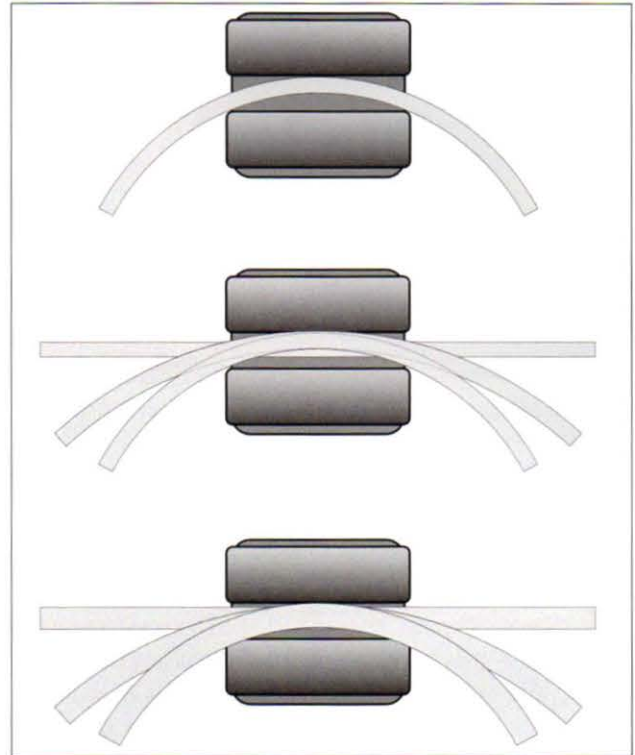
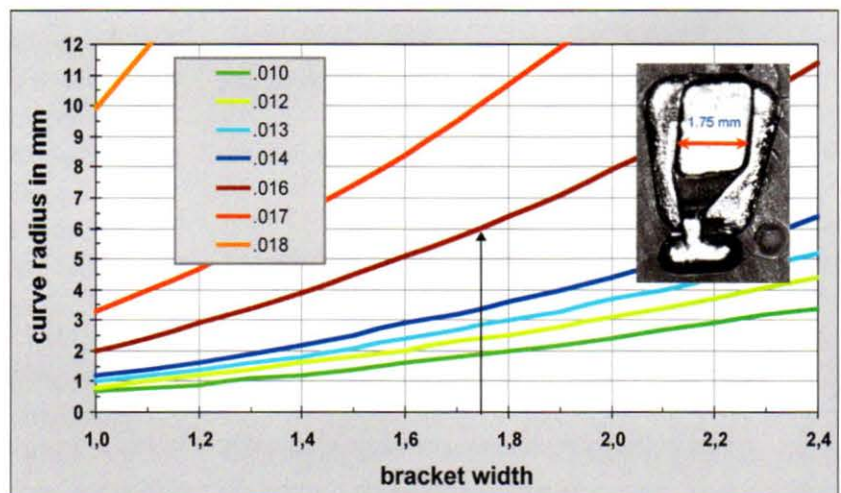


Fig. 5-8 Binding between the archwire and the bracket slot as a result of wire curvature. With less play between the wire and the slot, binding will occur with smaller smooth curvatures.

It has to be kept in mind though, that for brackets with horizontal slots, curvatures in the vertical plane are the important ones. In the horizontal plane the ligature usually allows for more play.

Fig. 5-9 Calculation of the critical curve radius for different bracket widths and wire dimensions. The actual slot size is assumed to be 0.0185. If the curve radius is smaller than the value derived from the graphs, binding with greatly increased friction will occur. For example, the illustrated ORMCO 7th Generation bracket has a slot length of 1.75 mm. With an 0.016 round wire, binding would occur with curve radii of 6 mm or less



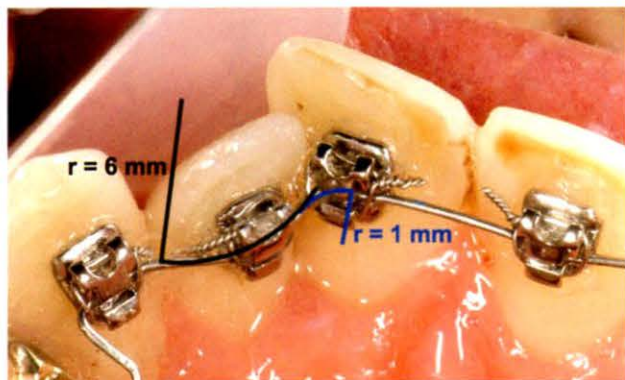


Fig. 5-10 Examples of curve radii in a clinical setting: the smooth curve at tooth (9)12 has a curve radius of around 6 mm while the tight curve of the archwire to the distal of the bracket on tooth (8)11 has a radius of only about 1 mm.

From the biomechanical considerations discussed above the following conclusions can be drawn:

- Thinner wires with some play between the archwire and the bracket slot are advantageous in all cases except when torque is required.
- The slot of anterior lingual brackets should be as close as possible to the labial surfaces of the anterior teeth.
- This leads to the necessity of positioning the brackets further incisally.

There are many benefits of using round wires for the whole treatment or part of the treatment, such as:

- significantly less complicated and less expensive laboratory process
- thinner bonding pads possible
- constant force development with no or insignificant force peaks with round superelastic archwire materials
- less friction because of less binding between the archwire and the bracket slot
- less unnecessary root movement.

With so many benefits of using thin round wires it makes sense to check during treatment planning in what category a patient falls: no torque necessary, torque may be necessary in later stages of treatment, or torque will be required throughout treatment. In the first case treatment should be carried out

with round wires and the laboratory process does not have to orient the bracket slots for buccolingual long-axis control. Rather the bracket bases should be as close to the enamel surface as possible and also near the incisal edge with orientation determined by vertical height, mesiodistal long axis, rotational control and possibly in-out. In the third case (torque necessary), the usual CLASS-type laboratory set-up procedure seems necessary. For the second category (some torque necessary at some stage) the orthodontist has to weigh the possible need to bend individual torque into the archwire at some stage against the higher cost and complexity of the CLASS-type set-up procedure.

Low-friction Ligation

One last feature completes the concept of light wire treatment in lingual orthodontics and that is low-friction ligation. Often archwires of relatively high stiffness and thus high forces are used to overcome the effects of friction. Friction is not only a problem during the intentional movement of teeth along an archwire, such as in sliding mechanics, but also during leveling. Here it is usually the archwire that has to move through the bracket as the initial irregularities of the teeth require excess wire length. There are some situations where high friction is not such a problem, for example when irregularities are to be resolved by proclination, but sooner or later friction will impede the efficiency of the leveling and further treatment. Figure 5-11 clarifies the problem: the example shows a situation where three brackets are bonded passively in line using a maximum size archwire. Then the low-force nickel-titanium test wire (16 Sentalloy light, GAC Intl.) is ligated and the center bracket is activated by moving it out of line (see inset) and then returning it to the passive, that is perfectly aligned, position. The force created by the wire and the extension of the center bracket from the passive position are measured continuously and used to create a force-deflection diagram. With high-friction ligation (elastomeric module, red line) the archwire very soon cannot generate enough force

Fig. 5-11 Influence of ligation-induced friction on forces generated by a low-force leveling wire (0.016 Sentalloy light, GAC). The high friction induced by elastomeric ligation (red line) completely eliminates any useful force below 2.2 mm activation, while in the absence of ligation-induced friction, the wire exerts light continuous forces all the way down to 0.3 mm displacement.

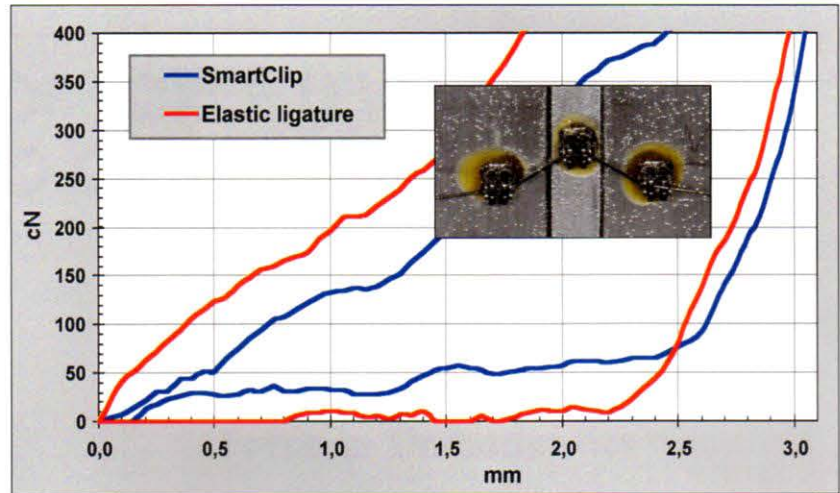
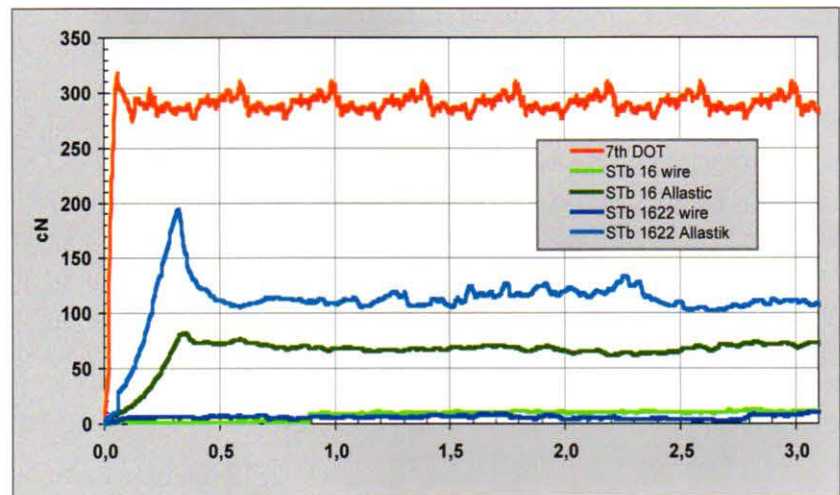


Fig. 5-12 Comparison of the resistance to sliding (= friction) of ORMCO 7th Generation lingual brackets with double over-tie ligation (red line) and ORMCO STb brackets with wire and elastomeric ligation.



to overcome friction and movement will cease or be severely reduced. With a low-friction ligation, in this case using the self-ligating mechanism of the SmartClip bracket (3M Unitek, USA) the wire goes on to exert small, continuous forces almost until the perfect alignment of the three brackets.

Traditionally, lingual brackets have been almost exclusively ligated using elastomeric ligation. In the case of the ORMCO 7th Generation bracket, usually the so-called “double over-tie ligation” was used to press the archwire into the slot. Measurements show that this creates very high friction values (Fig. 5-12). The STb bracket was designed so as to reduce the friction due to ligation with conventional

elastomeric module ligation and almost eliminate it when steel ligation is used. Because of the design of the bracket, it is relatively easy to use 0.2 mm soft ligation wire for the ligation of these brackets. As can be seen in Fig. 5-12, the friction is reduced by more than 95% in relation to the double over-tie with ORMCO Kurz 7th Generation brackets. This low friction complements the use of thin and low-force orthodontic leveling wires. The use of steel ligatures completes the concept of light wire lingual orthodontics: Use light wires for optimal ease and efficiency and switch to heavy, slot-filling, wires only when they are required for the task at hand.

6 THE EFFECT OF FORCE LEVELS ON TISSUE REACTION TO ORTHODONTIC LOAD

Carlalberta Verna

Introduction

Orthodontic treatment is the result of interaction between the orthodontist, who could be considered as a "guest", and the patient, ie, the "host". This is true for all aspects of the treatment, from the macroscopic level of clinical management to the microscopic level of the tissue reaction. The optimal treatment would thus be one that combines the best comfort for the patient and the orthodontist at a macroscopic level with the lowest "discomfort" for the supporting tissues, ie, at a microscopic level. In practical terms, this would involve the achievement of the desired tooth movement within the shortest treatment time, without tissue damage and discomfort to the patient.

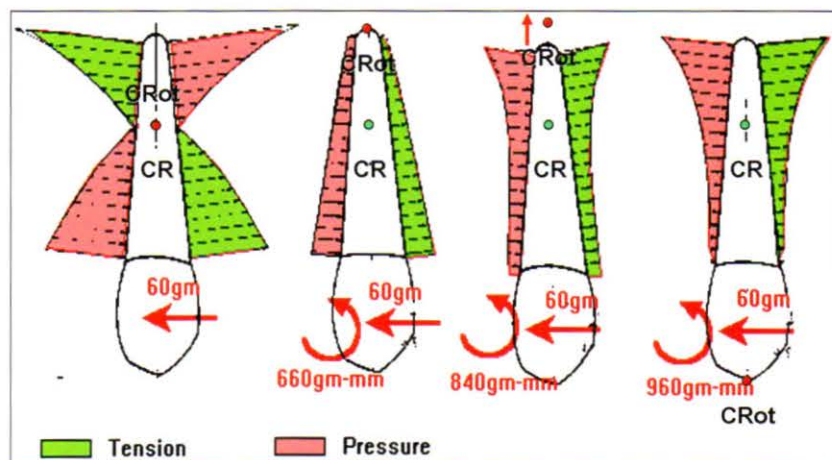
The concept of fast treatment and minimum damage was discussed as early as the 1970s by Andreasen during the development of nitinol archwires (Andreasen 1980). In the past decade particular attention has been paid to these aspects, reflected in the increased availability of new bracket systems that aim to help achieve faster movement with less pain for the patient and respect for the supporting tissues.

This chapter will consider the effect of force level on orthodontic tooth movement, focusing on the tissue reactions of the structures loaded by the orthodontic appliance: the periodontal ligament (PDL), the alveolar bone, and the tooth roots. The reactions of the cellular and extracellular elements and the mechanical behavior of each structure, which is controlled by both local and systemic factors, will be discussed.

Some Basic Concepts of Force in Orthodontics

The terms "light forces" and "heavy forces" are extensively used within orthodontics and these forces have been described in relation to the biologic reaction to an orthodontic force system. However, a common clinical observation in daily practice is that different patients exhibit different responses to the same mechanical loading. Animal studies performed under controlled experimental conditions have confirmed this observation, emphasizing the role of individual factors in the tissue reaction to orthodontic loading. Thus the relationship between forces and tooth movement is more complex than it appears, and raises the question whether it is appropriate to discuss the influence of force level from the biologic point of view.

First, in order to define a heavy or a light force, a threshold has to be found that will distinguish between the two force ranges. At present, at least in relation to the speed of tooth movement, it is not clear at what force level the teeth move faster. Moreover, the tissue reaction is not dictated by the absolute amount of force applied, but rather by its distribution within the PDL. The orthodontist controls the local stress-strain distribution by varying the line of action of the force, which is determined by the moment-to-force ratio delivered at the bracket (Fig. 6-1). The force level is determined by the archwire composition, its dimension, and its length, ie, the inter-bracket distance. The way the force is delivered to the tissues has been classified as: continuous, interrupted continuous, and intermittent. However, the variation in the stress-strain distribution is also influenced by function, such as chewing, swallowing, etc. (Fig. 6-2).



Figs 6-1 Theoretical illustration of the distribution of tension and compression in the periodontal ligament. The areas of tension and compression, or in other words the stress-strain distribution, become more homogeneous with increasing distance between the center of resistance (CR) and the center of rotation (CRot). At the level of CRot, neither stress nor strain is present. In case of translation, pressure is uniformly distributed along one side of the tooth. Figure 6-1b and 6-1c are examples of approximate translation. (From Libra Ortodonzia, with permission.)

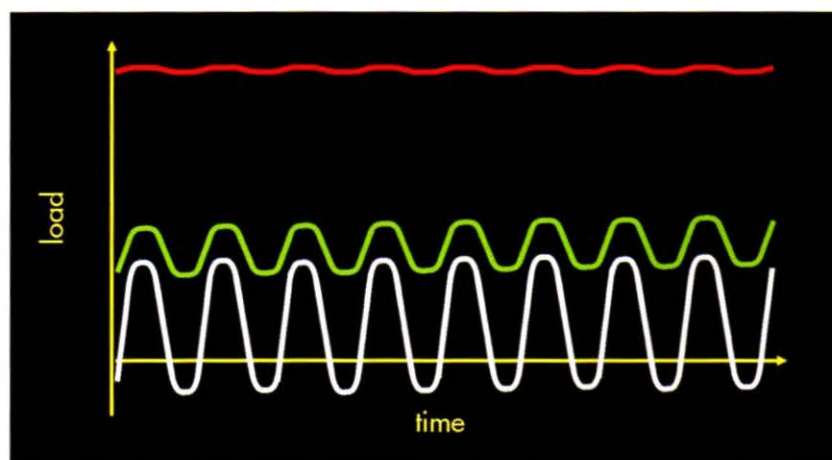


Fig. 6-2 The rhythmic activity of mastication (white line) interferes with the type of force delivered by an orthodontic appliance. The lighter is the force (green line) the larger is the influence of the chewing activity. In other words, the so called continuous light forces are in reality intermittent forces because of the interference of mastication. The use of high forces (red line) ensure better constancy of force level, as the forces of mastication do not affect the force. However higher forces are more detrimental for the periodontal ligament. (From Libra Ortodonzia, with permission.)

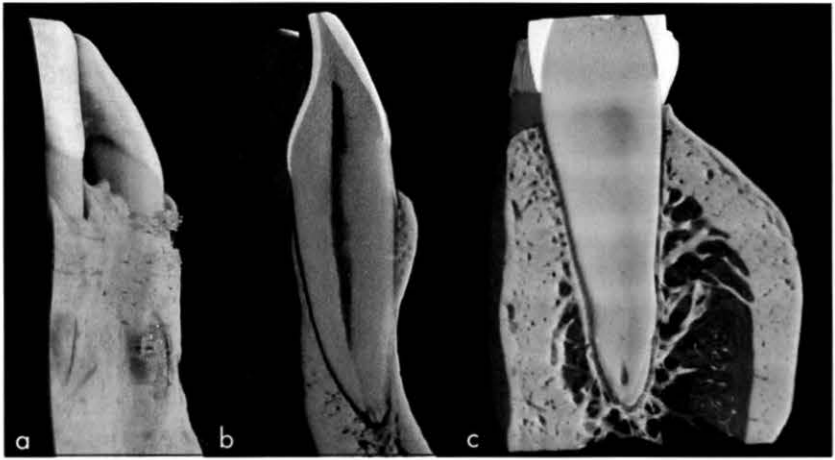
The magnitude of the stimulus has to be above the threshold for the initial reaction and the duration of the stimulus long enough to initiate the cascade of biologic reactions. Because of the viscoelastic nature of the PDL the magnitude and the duration of the stimulus are mutually dependent. It has been demonstrated that a force of 4 g on a tooth *in vivo* is sufficient to initiate a sequence of reactions identical to that seen in orthodontic tooth movement, provided there is no interaction with the surrounding environment.

The magnitude of the applied load, the "optimal force", also needs to take into consideration the variation in the supporting tissues among individuals as well as between different areas of the mouth in the same individual and whether the force is being applied to one or more teeth at a time. It has been suggested that necrosis occurs when the

force exceeds capillary blood pressure (between 20 gm/cm² and 47 gm/cm²), as a consequence of total ischemia of the PDL. A uniform distribution of the strain, as in the case of bodily movement, would prevent the concentration of stresses in specific areas of the PDL, decreasing the risk of over-stressing the PDL and its vessels. However, owing to the irregularity of the alveolar wall (Fig. 6-3), even with low force levels small patches of hyalinization appear in all stages of treatment and seem to be related to the rate of tooth movement.

The force regimen may have a greater role in orthodontic tooth movement than the force level itself. Continuous force regimens would, in spite of a larger lag phase, lead to larger tooth movement. Fixed appliances tend to deliver continuous forces but, provided the force level is kept low, fluctuation in the stress-strain distribution in the periodontium

Fig. 6-3 The three-dimensional (3D) morphology of the teeth and the periodontal tissues assessed with micro-computed tomography (μ CT). (A) The fenestrated alveolar wall. (B) The thickness of the alveolar wall varies and in some places it is not much more than that of the periodontal ligament. (C) The wall is supported by an intricate network of interconnecting trabeculae that are thinner and more sparsely distributed towards the apices of the roots. What is usually called lamina dura is not a uniform structure. It can be clearly noticed that in the cervical area, the alveolar bone facing the periodontal ligament is characterized by a series of small pores through which pass the periodontal fibers and vessels, evidence of biologic pathways between the PDL and the alveolar bone. At the cervical aspect, the alveolar wall merges with the lingual and buccal cortical plates, thus enhancing the mechanical support.



occurs and the biologic reaction thus simulates the one generated by an intermittent force. Only in the case of a stainless steel archwire and a short inter-bracket distance would the PDL perceive the orthodontic force system as continuous. In experimental studies in long bones, continuous loads did not elicit any biologic reaction whereas application of intermittent loads resulted in an increase in bone activity, which maintained the bone architecture (Lanyon 1992). This may explain why copper nickel-titanium (CuNiTi) wires with a transition temperature of 40°C appeared to result in more rapid leveling than those with a transition temperature of 27°C. A transition temperature of 40°C allows for the delivery of low, intermittent forces. The force regimen also encompasses the traditional anchorage principle of “more teeth against few teeth”, where the biologic reaction is delayed around the anchorage teeth by the use of stiff stainless steel archwires.

Another traditional orthodontic concept is that there is a linear relationship between the magnitude and amount of tooth movement. However, the finding that different force levels can result in the same rate of tooth movement does not support this assumption. High force levels do not necessarily enhance tooth movement and overloading the periodontal tissue can cause negative effects,

such as hyalinization and ischemia, thereby actually delaying tooth movement. In reality no linear relationship exists and there is no biologic basis for absolute tooth anchorage. The success of temporary anchorage devices (TADs) is thus not surprising, since they have moved the limits of orthodontic treatment.

Second, the mechanical perturbation induced by the force has to be considered in relation to its targets, namely the PDL and the alveolar bone. It has to be emphasized that in the literature the greatest attention has always been focused on the PDL surface, extrapolated by the root surface area calculation. Freeman (1965) assigned anchorage values based on the root surface area and applied this to the Begg technique. In reality, it is not the root surface that we are interested in, but the alveolar bone surface. Figure 6-3 is a high resolution micro-computed tomography scan of a human bone sample comprising the tooth and the surrounding alveolar bone. It can be clearly seen that only a weak correlation exists between the surface of the root and that of the alveolar wall: the stresses and strain are not distributed over homogeneous surfaces, but, on the contrary, over a structure that, at a microscopical level, is characterized by a highly uneven surface. The micro-anatomy of the alveolar wall indicates that only very small forces

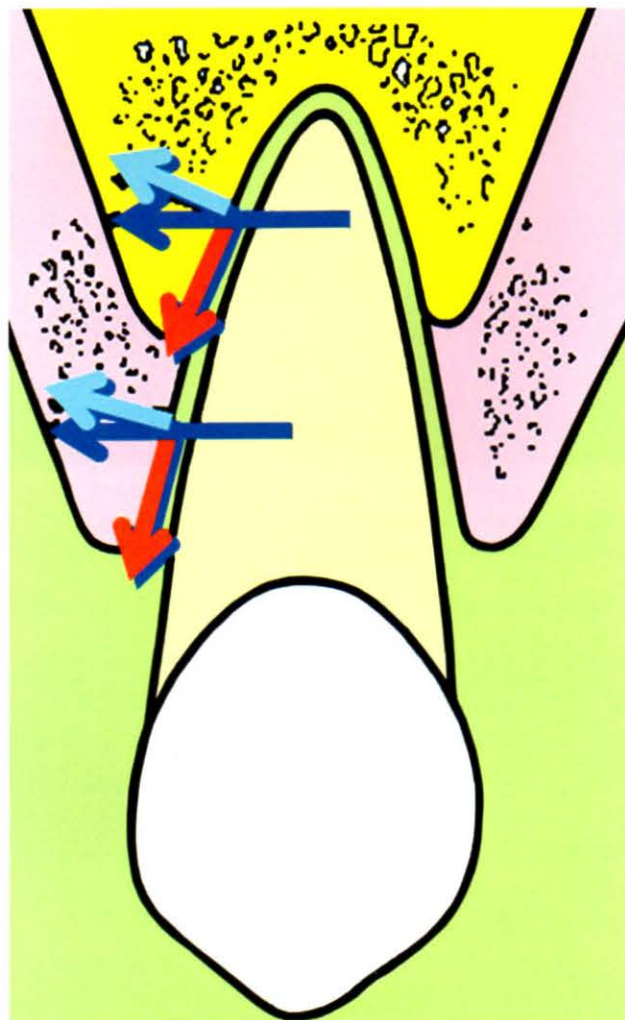


Fig. 6-4 Illustration of the cone effect. When a force is applied on an inclined plane the resolution of the force results into a horizontal and a vertical component. The latter, when not properly controlled, leads to extrusion. (From *Libra Ortodonzia*, with permission)

should be applied in order to avoid ischemia and local necrosis. As a consequence, the stresses and strain sensed by the PDL cells do not necessarily mirror the ones sensed by the bone cells.

Thus from the above discussion it is clear that individual anatomic variation, together with genetic and metabolic characteristics, may explain the inter-individual variability in the rate of tooth movement that occurs at similar force levels.

The Three Targets of Orthodontic Force Application

Periodontal Ligament

The precise steps in the cascade of events that transform a mechanical perturbation into a biologic reaction are still unknown. The investigations are complicated by the fact that the mechanical load is applied via the tooth to two different structures: the PDL and the alveolar bone. The complexity of the matter has led to a semantic misunderstanding, of which the orthodontic literature has been a victim in the past. The classical association described between pressure and resorption in the PDL has been also extended to the alveolar bone. However, the alveolar bone does not respond to force in the same way as long bones, as described in the orthopedic literature, where compression of long bones has been shown to be associated with bone formation (Casagrande and Frost 1953). A more proper description of the events occurring at the cellular level is a reaction to difference in strain, since cells cannot discriminate between pressure and tension.

The initial tooth movement is mainly because of the displacement of the tooth within the PDL, deformation of the PDL and of the alveolar bone, and extrusion. Extrusion is due to shearing and has been referred to as the "cone effect", resulting from a horizontal force being applied to an oblique surface (Fig. 6-4). It is usually counterbalanced by the tension of the supracrestal fibers, but when the PDL support is poor, extrusion is more evident. The baseline mechanical load is modified by the orthodontic load, and the periodontal fibers, the cells, and the extracellular matrix (ECM) are submitted to deformation.

Cellular metabolic activities are related to cell deformation and the cytoskeleton is physically coupled to the ECM via integrins, thus fine tuning the cellular response at a gene regulation level. Cells are sensitive to mechanical insults from trauma, and on application of orthodontic force, it has been found that PDL cells exhibit disruption of the cytoplasmic membrane followed by repair. Together with plasma membrane deformation, changes in fluid flow within the PDL generate shear stresses. The

dynamics of fluid flow in the PDL is mainly maintained by the vascular system which plays a central role in orthodontic tooth movement, since 50% of the PDL volume is occupied by blood vessels, with the highest percentage on the bony side. In the area toward which the tooth is moved, partial or complete occlusion of vessels is observed after 24 hours when the concentration of stresses exceeds the capillary blood pressure, leading to necrosis and hyalinization. Vascularization is re-established after about 7 days by invasion of vascular structures into the hyalinized areas. On the tension side, blood supply is increased, the blood vessels are dilated and, together with vascular infiltration, macrophage and leukocytes migration is seen, along with chemotraction, mitogenesis, and cytodifferentiation.

The PDL fibroblasts are spindle-shaped and oriented in the same direction of the principal fibers, a sign of mechanical deformation. Collagenases produced by osteoblast-macrophage interactions reduce the fibrous component of the PDL and the related mechanical strength. Osteoid deposition occurs along the thick fiber bundles and subsequent calcification into new bone starts from the deeper layers towards the surface (Fig. 6-5).

The changes in density and distribution of blood vessels during tooth movement have been shown to be related to changes in neural response. Many sensory neuropeptides are released during tooth movement, and this is related to the experience of pain and discomfort. Cell kinetics studies have demonstrated a differentiation gradient from the blood vessels toward the root following the application of an orthodontic force, with the most undifferentiated and proliferating cells being found in the perivascular sites. It has been suggested that the mechanical signal may be targeting osteoblast precursors in a state of readiness to respond to an environmental challenge, without the need of an initial proliferative response. The final result is an increased production of collagen and increased synthesis of ECM, with up-regulation of anti-apoptotic factors and increased metalloproteinase 8 production, as detected in crevicular fluid. Obstruction of blood vessels probably delays this response and, as a consequence, tooth movement will be impaired.

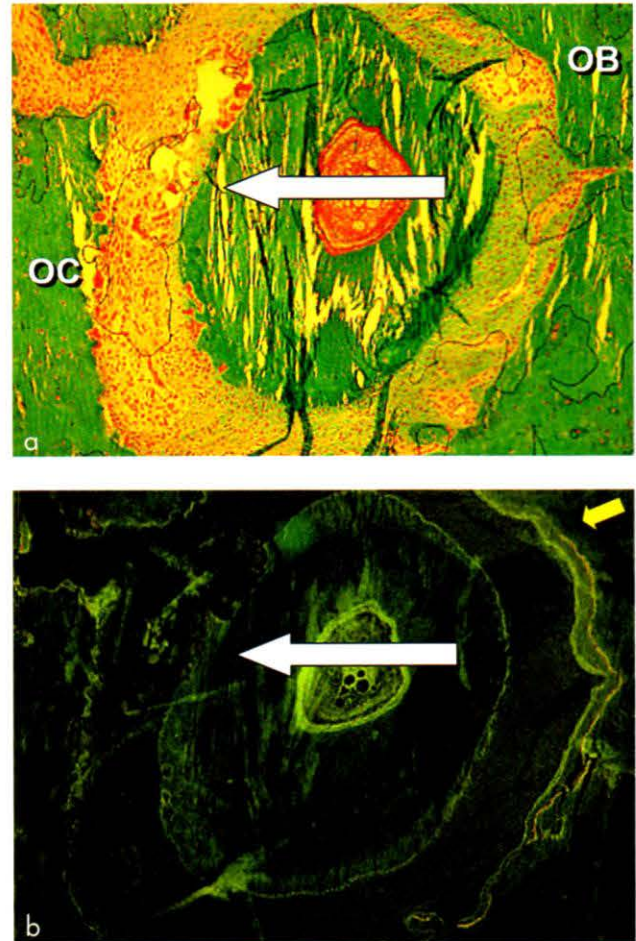


Fig. 6-5 Thin, undecalcified histologic section of a rat molar which was moved in the direction of the white arrow for 14 days. (A) Goldner Trichrome staining, showing osteoclasts (OC) in the alveolar bone facing the periodontal ligament (PDL) in the direction of the force. On the opposite site, osteoblasts (OBs) are lining the alveolar bone surface and produce new bone. (B) Fluorescent light histologic picture showing mineralizing bone in the area where OBs have produced new bone (yellow arrow). The distance between the green line (calcein) and the yellow line (tetracycline) represents the amount of bone produced between the time of administration of the two bone markers and is a sign of the rate of bone formation. Note that there is no labeling in the alveolar bone toward which the tooth is moving, since the surface is covered by OCs.

Alveolar Bone

Orthodontic tooth movement has been described as a displacement of the alveolar process by modeling, with bone resorption in the direction of the force and bone formation on the opposite side. In the direction of the applied force, the PDL width

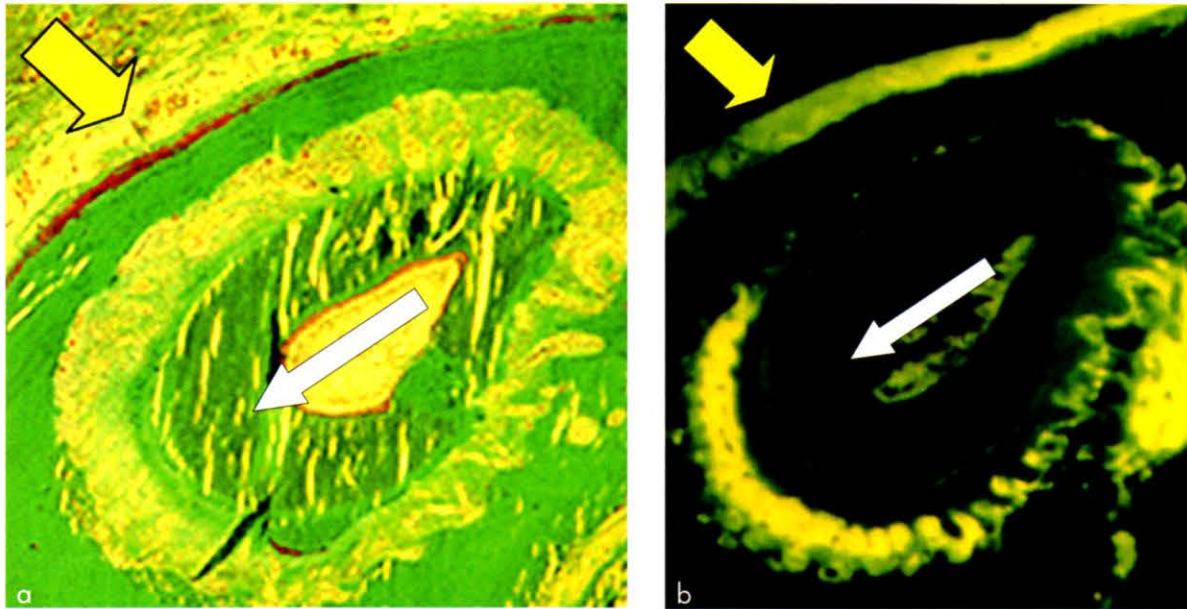


Fig. 6-6 Thin, undecalcified histologic section of a rat molar which was moved in the direction of the white arrow for 21 days. (a) Goldner Trichrome staining. (b) Fluorescent light image. On the periosteal side (arrow) and in the direction of the force (at a certain distance from the alveolar wall) new bone formation occurs, in order to maintain the thickness of the alveolus and ensure tooth support.

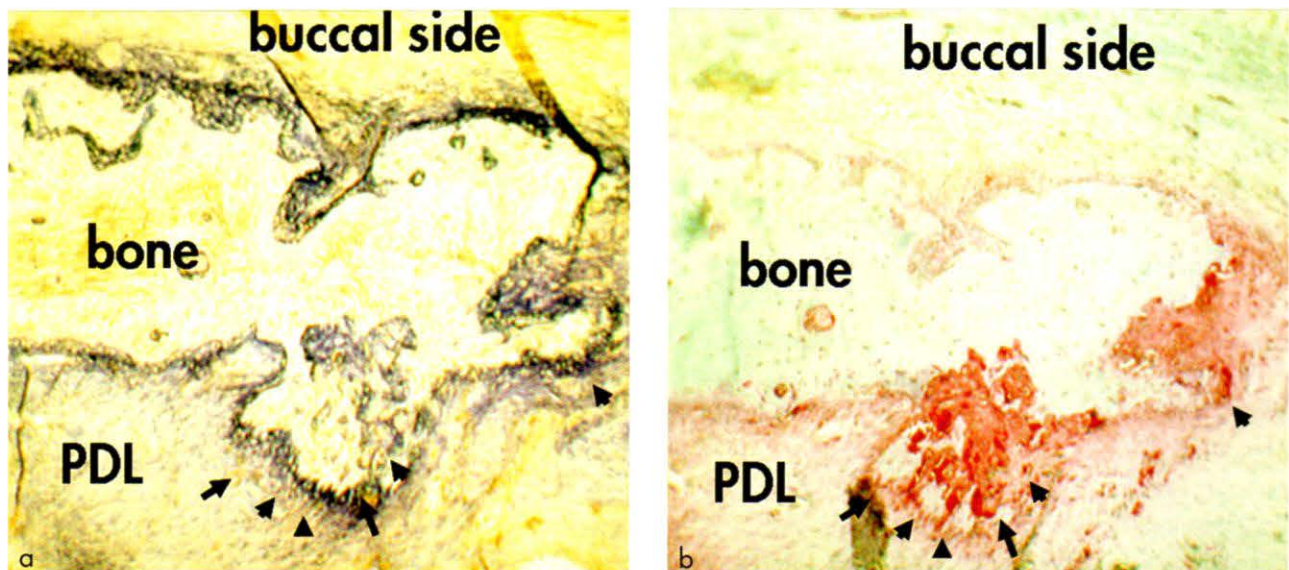


Fig. 6-7 Thin section of alveolar bone on the buccal side of a rat tooth after 14 days of orthodontic treatment. On the side facing the periodontal ligament the bone had stained positive for both alkaline phosphatase (marker for bone formation (a)) and for acid phosphatase (marker for bone resorption (b)). (From Libra Ortodonzia, with permission.)

and bone thickness are maintained through apposition, thus resulting in drift of the whole alveolus (Fig. 6-6). However, bone formation has also been demonstrated on the side of the direction of the force, and bone resorption on the so-called tension side

(Fig. 6-7), demonstrating that bone remodeling also occurs during orthodontic tooth movement. Remodeling enables bone to adapt to mechanical stresses and minimize fatigue damage, and is influenced by the action of hormones and cytokines. Movement of

the tooth socket occurs due to a modeling process, while its internal renewal is due to remodeling.

The alveolar bone supporting the teeth subjected to an orthodontic force undergoes deformation which is inversely proportional to the distance from the tooth apex. Mechanical loads are translated into bone strain in the order of 0.2%, due to the stiff nature of intact *in vivo* bone. The change in shape is such so that the tooth-supporting structures resist the challenge in the optimal way. A link between change in shape and biologic activities in the alveolar bone was proposed by Epker and Frost in 1965, who suggested that on surfaces becoming less concave, resorption activities tend to prevail, and on surfaces becoming more concave, bone formation occurs. During tooth movement, the so-called "pressure" side become flattened (less concave) and the opposite side tends to be more concave, by being pulled by the periodontal fibers under tension (Fig. 6-8).

More recent stress analysis by Cattaneo and co-workers (2005) has shown that the transfer mechanism of orthodontic loads through the alveolar supporting structures cannot be explained in terms of compression and tension (Fig. 6-9). In the area from which the tooth is moving, both compressive and tensile strains are present, though very little compressive strain is present in the bone in the direction of the force. Thus, better terms to use with regard to bone mechanical perturbation are loading and unloading. The areas traditionally said to be the ones where tensile stress components are present would be better called loaded areas. The areas called compression areas are, according to stress analysis, areas where the baseline load applied by the periodontal ligament fibers is in reality diminished, because the PDL becomes curled up, and practically no stresses are transferred onto the alveolar wall, shown by the fact that there is no hyalinization, which would produce a different load transfer pattern. Resorption activities will prevail where the load is reduced and bone formation will occur in areas where the load is increased. The term compression is, however, still valid in the case of over-compression of blood vessels and PDL constituents, which leads to ischemia and subsequent hyalinization.

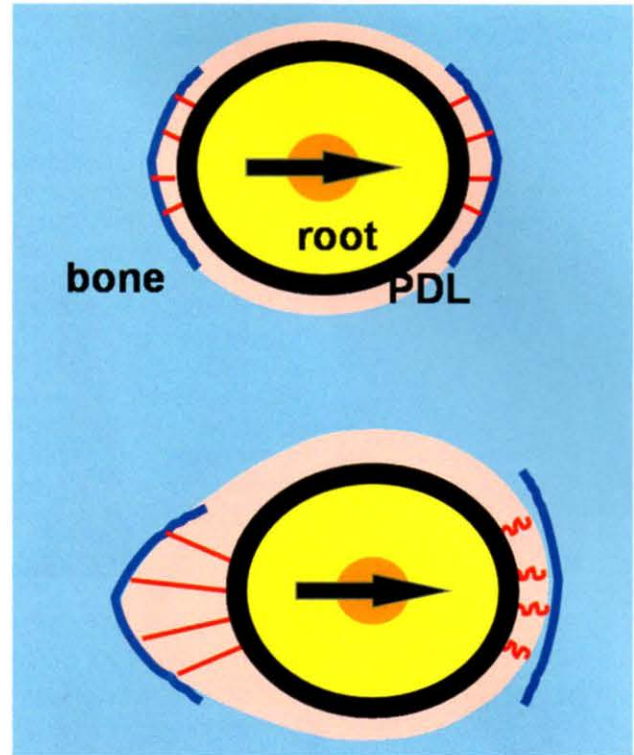


Fig. 6-8 During tooth movement the so-called "pressure" side becomes less concave, with the periodontal ligament (PDL) fibers relieved from the baseline tension they are usually subject to. On the opposite side the alveolus tends to be more concave, as it is pulled by the periodontal fibers. The changes in shape of the bone surface are called local strain operators, and, together with the load applied to the whole bone, influence the biologic behavior in mechanically induced modeling. On the bone surface that becomes less concave, resorption activities tend to prevail; on surfaces becoming more concave bone formation usually occurs. (From *Libra Ortodonzia*, with permission.)

The possible candidate for the mechanosensory transduction of force is primarily the interconnected cellular network of osteocytes, osteoblasts and lining cells. Osteocytes are able to "normalize" their local mechanical environment by modulating their cytoskeletal architecture, attachment to the matrix, configuration of the periosteocytic space, and communication channels with the surrounding cells. They participate in the formation and/or resorption of bone by coordinating site-specific recruitment of osteoblasts and/or osteoclasts. The electrical charges generated by streaming generated poten-

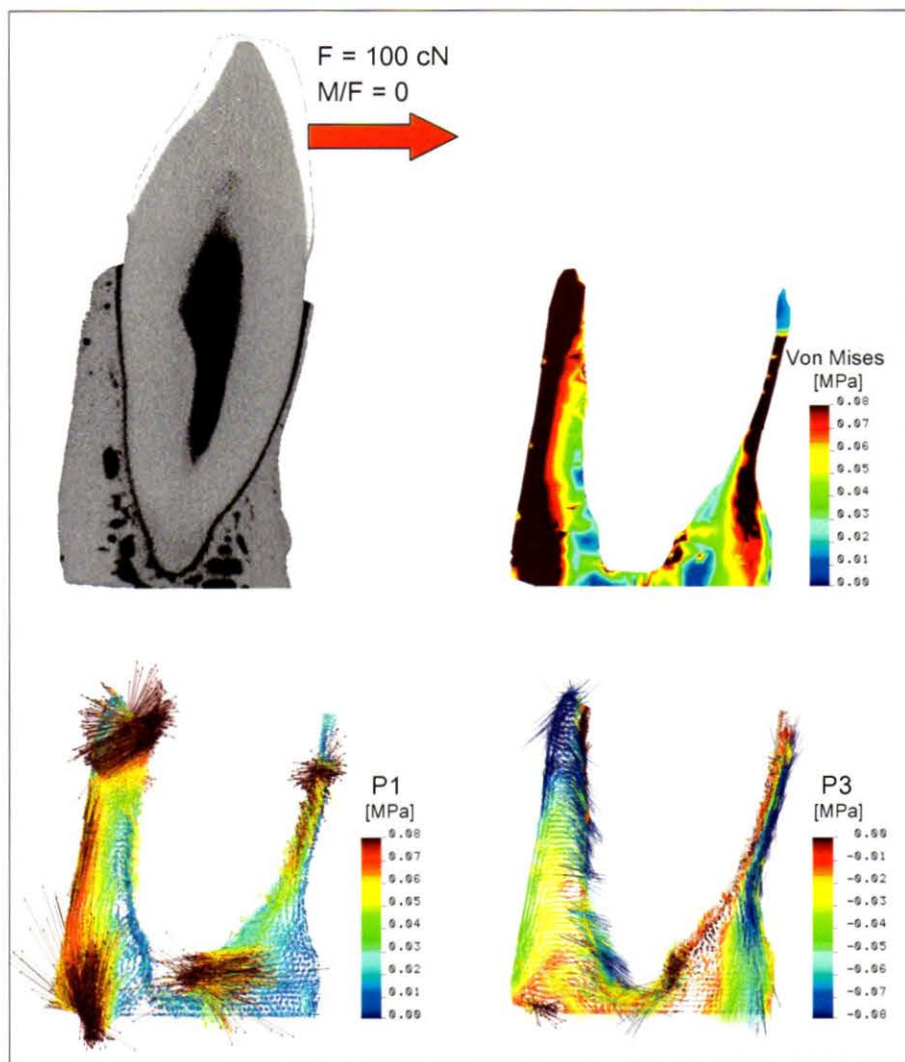


Fig. 6-9 Stress distribution in a buccolingual section of the alveolar bone when a tipping loading regimen is applied at the bracket. The Von Mises stresses are higher on the lingual side (the “traditional” tension side) than on the buccal side (top right panel). The first principal stresses (bottom left panel) show that the highest tensile stresses are present at the lingual side due to the bending of the alveolar bone and by the pulling action of the periodontal ligament (PDL) fibers in the linguocervical and buccal-apical regions. The third principal stresses (bottom right panel) show that the highest compressive stresses are present at the linguocervical region and along the buccal wall. Note that the presence of tensile stresses does not exclude the presence of compressive stresses in the same area and vice versa. (From Elsevier with permission.)

tials could affect osteocytic cell somatic processes that, through secondary messages, could transmit the signal to the osteoblasts and lining cells via the interconnecting network. At the same time other streaming potentials generated by the interstitial fluid could amplify the message. The interaction of the various types of cell would ultimately transmit the mechanical load signal to the system.

Stretch-activated ion channels have been found on bone cells, meaning that a direct mechanical deformation of the cell membrane cannot be excluded. At a tissue level, bone micro-damage increases with fatigue loads at physiologic levels. It is associated with bone remodeling and osteocyte apoptosis, and a significant increase in crack density in

the direction of force has been found following the application of an orthodontic force. Generation of micro-cracks with the application of an orthodontic force seems to be likely, especially in areas with bony spicules, where there is high concentration of forces over a small surface area (see Fig. 6-3). This might once more explain the finding that small areas of hyalinization are unavoidable.

The effector cells of the mechano-transduction are the osteoclasts, since bone resorption is needed before it can adapt to the new mechanical environment. Bone surfaces covered by the hyalinized PDL cannot be resorbed directly by cells coming from the PDL. The lack of blood flow in the area also leads to a disappearance of the lining cells and the osteo-

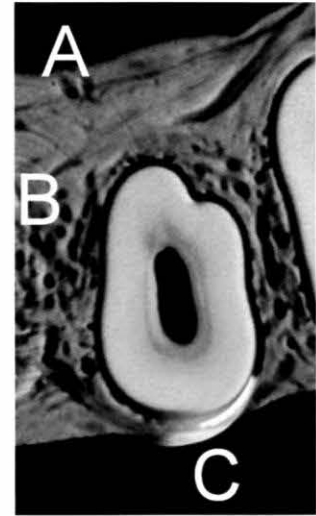
cyte lacunae in the adjacent bone appear empty as a result of apoptosis. The necrotic tissue is thus removed by cells coming from other compartments depending on the anatomic situation: the bone marrow, the cortical bone, or the periosteum. When indirect resorption is initiated at the cortical bone, the lower cellularity of the cortical bone requires more time for the activation of the movement and, if enough time is allowed for bone formation at the periosteal side, the tooth will move with the alveolus, ie, with bone (A in Fig. 6-10). When indirect resorption occurs from the periosteum, the probability of bone fenestration increases (B in Fig. 6-10). It is of utmost importance in those cases to avoid, as much as possible, the obstruction of blood vessels by the use of low forces uniformly distributed along the PDL. As the alveolar bone is not being resorbed from the surface, no tooth movement will take place until the hyalinized areas are resorbed, after 3 to 5 weeks. The formation of bone in the direction of the force at a distance from the PDL is considered to be a reaction to the strain on the bone generated by the deformed alveolus, as in bone healing processes (see Fig. 6-6).

Root Surface

External root resorption is a phenomenon that has been associated with orthodontic treatment. However, direct causal factors have not been identified yet. The lack of consistent findings in the research has led to a different approach to the analysis of the problem, ie, looking for the primary causative effect more among variables related to the patients rather than the treatment. Among the patient-related factors recent studies have considered the possible role of genetics, the immune system and the patient's medical history. A meta-analysis of treatment-related factors of external apical root resorption showed that the total distance the root apex is moved and the treatment duration are risk factors (Segal et al 2004). Regarding the type of treatment, it has been suggested that fixed appliances are more detrimental than removable ones.

The amount of force applied has also been a matter of debate concerning root resorption. Negli-

Fig. 6-10 The compartments from which necrotic bone tissue can be resorbed: cortical bone (A), cancellous bone (B), and periosteum, in case of thin cortical bone (C). Notice that the three different anatomic situations may occur around the same tooth, meaning that the same response cannot be expected when the tooth is moved toward A, B, or C. The intra-individual variability of the alveolar wall surface is also well illustrated



gible root resorption has been found with light (15 g per tooth) intrusive forces in adolescents, whereas force levels leading to the obstruction of blood vessels may cause root resorption. Once a certain level of force is reached, a double or four-fold increase in force does not increase the risk for root resorption. Research in this field has been greatly improved by the use of three-dimensional analysis. The volumetric analysis of root resorption of the depth and width of resorption craters has revealed that high forces generate 3.31-fold greater total resorption than light forces (Fig. 6-11).

As discussed above for the PDL and the alveolar bone, the regimen and the duration of the force seems to influence the reaction at the root surface. Continuous forces result in more root resorption than intermittent forces, probably due to the lack of time allowed for repair. The finding that use of superelastic wires is associated with more root resorption than is the use of stainless steel wires is in line with the observation that time for repair is required to delay the formation of resorption craters.

Conclusion

Proper use of force enables the clinician to perform tooth movement otherwise considered impossible (Fig. 6-12). The orthodontist can control the magnitude, the distribution, the regimen of the force appli-

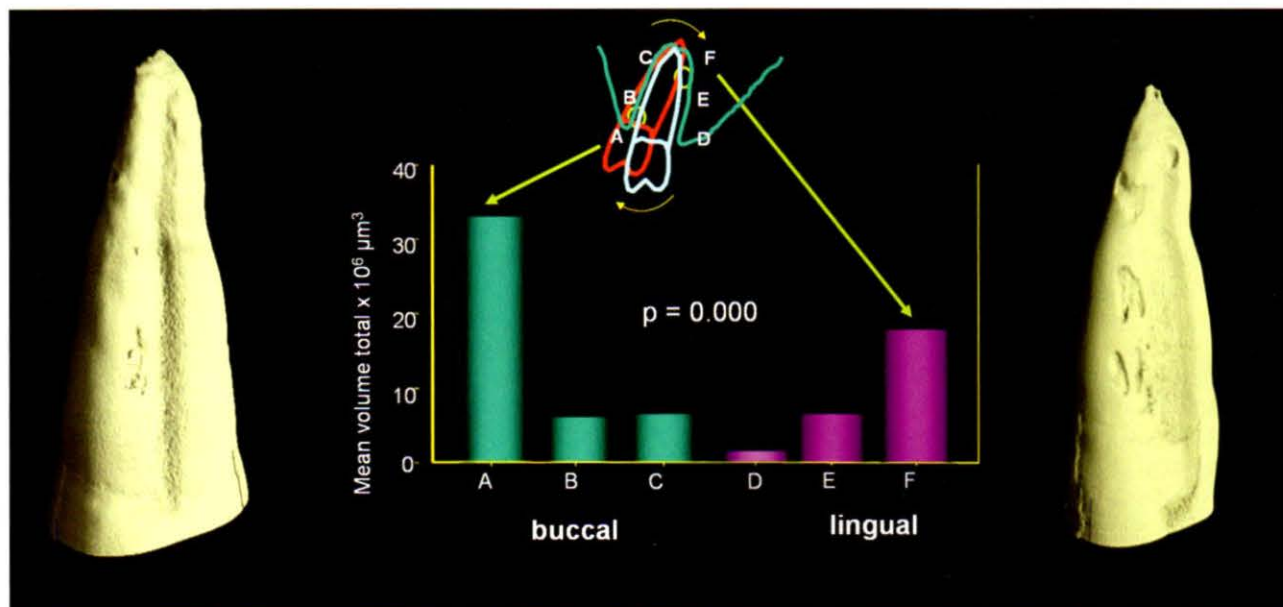


Fig. 6-11 The volume of the resorption craters in the case of light forces (left root) is smaller compared with the volume related to heavy forces (right root). The diagram illustrates graphically that under buccal tipping forces, higher compressive stress on the lingual apical and buccal cervical regions creates resorption craters whose volume is significantly higher than in the other regions. (Modified with permission from Elsevier.)

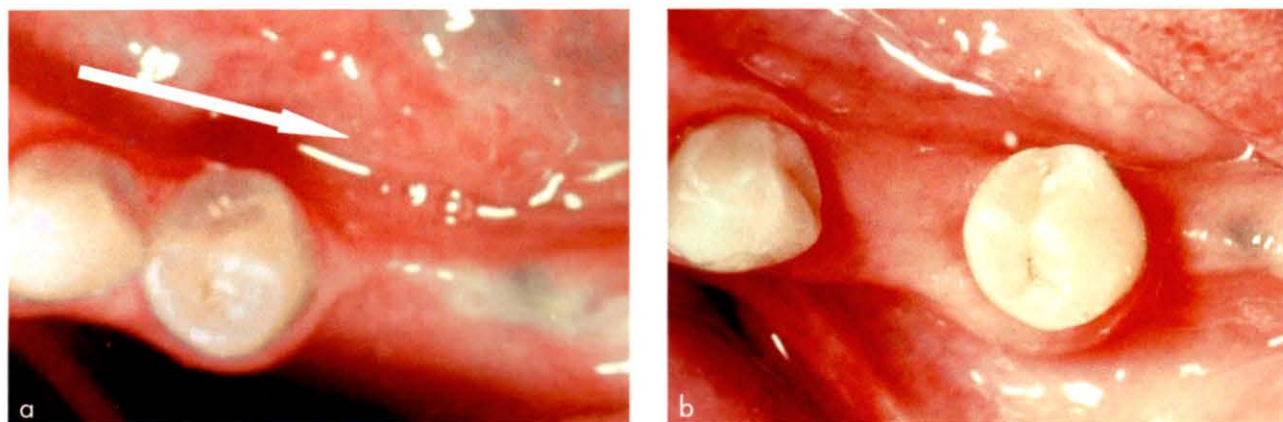


Fig. 6-12a,b The appropriate moment-to-force (M/F) ratio allows for a stress-strain distribution within the periodontal ligament and the alveolar bone that leads to tooth movement with bone, as in the case of a premolar moved towards an edentulous area. (Courtesy of Dr A. Fontenelle.) Note bone formation on the mesial side that can be used for implant placement, thus widening the options available for oral rehabilitation.

cation, whether continuously or intermittent, and the duration of the treatment. The magnitude of the force generated by a fixed orthodontic appliance depends on the material composition of the archwire, its dimensions, and its length, in addition to the degree of activation. In the lingual technique the

vertical leveling delivers generally smaller moments compared with the labial technique, as the line of action is closer to the center of resistance. As a consequence, in the lingual technique, to achieve the same moment-to-force ratio obtained with the labial technique, lower forces should be used.

An optimal force level showing an ideal dose-reaction relationship between the magnitude of the orthodontic load and the rate of tooth movement has not been identified yet. The displacement of a tooth is not linearly related to the applied load. At low force levels, larger tooth displacement is observed compared with higher force levels, and, as a consequence, the use of high forces is not advisable.

The variable anatomy of the alveolar supporting tissues in different individuals plays a role in

the distribution of the stresses and strains in tissues. The mechanical properties of the supporting tissues are non-linear and inhomogeneous even within the same tooth. This makes the load transfer through the alveolar tissues more complex than expected. Since very small forces are enough to initiate tooth movement and cause less serious damage to the root surface, their use is recommended in order to avoid ischemia, local necrosis, and tissue damage.

7 NEW DIAGNOSTIC CONCEPTS IN ORTHODONTIC TREATMENT WITH THE SYSTEMATIC STB LOW-FRICTION SYSTEM

with Luca Lombardo

The new therapeutic options have resulted in a radical change in the diagnostic approach to the orthodontic patient. The assessment of crowding has completely changed from the traditional method of starting from the angulation of the mandibular incisor with respect to the mandibular plane and concluding with various expansion and distalization options.

Mandibular Versus Maxillary Incisor Position

Severe crowding no longer necessitates extraction treatment if the upper incisors are in a good position, that is, the upper incisors are in an acceptable position from the esthetic and, especially, functional point of view. In the course of the past few years, the concept of "esthetics" has also changed: as stated above the position of the mandibular incisors is considered less binding, while increasing attention is paid to the position of the upper incisors in the attempt to obtain less flat profiles. Indeed, a review of extraction cases treated 20 years ago reveals that these patients develop an "early aged" look, because of the lack of support for soft tissue by the hard tissues (teeth and alveolar bone) (Witzig and Spahl 1987; Spahl 2003; Bowman and Johnston 2007). This has led orthodontists to be wary of extractions in many patients or to feel less anxious about loss of anchorage in the anterior segments.

The position of the mandibular incisor should be considered with respect to the functional condition of the surrounding soft tissues, especially the upper and lower lip, and the periodontal structures. Today we are ready to accept mandibular incisor

tipping values in excess of the values proposed by Tweed, provided that the periodontium is absolutely healthy.

Tweed drew attention to the angle between the mandibular incisors and the mandibular plane, and emphasized extraction treatments, which confined the orthodontist's treatment planning to the task of selecting a stable position for the mandibular incisor and, following this, to moving the maxillary incisors to achieve contact with the mandibular incisors.

Orthodontic Analysis Based on the Maxillary Incisor Position

Today, within the framework of modern orthodontics, the first step in the treatment plan is focused on assessing the functional and esthetic position of the maxillary incisors with respect to the maxillary plane, the normal value of which is 110 degrees. Arnett prefers to identify the angle of the maxillary incisor in relation to the maxillary occlusal plane, the normal value for which is 56 degrees in women and 57 degrees in men (Arnett and Bergman 1993a, b).

Any plan to move the mandibular incisors should aim to achieve good contact of these incisors with the maxillary incisors: this is attainable by means of movement within the mandibular bone, which basically consists of a change in the angulation of the mandibular incisors, or increase in mandibular length, or a change in the anteroposterior position of the mandible following repositioning of the condyles in the articular fossae.

Ellis and McNamara (1986) believe it is crucial to determine whether tooth position is normal, pro-

truded or retruded with respect to the basal bone. So to calculate the maxillary incisor position, he uses measurements that relate the maxillary dentoalveolar processes to the basal bone of the maxilla. He measures the distance between the perpendicular to the Frankfurt Horizontal Plane passing through point A and the labial surface of the incisor; the normal value for this distance is 4 to 8 mm.

The cephalometric soft tissue analysis proposed by Arnett is of great help to both the orthodontist and the surgeon in evaluating the facial profile and harmony. It is important to assess the vertical position of the maxillary incisors on a tracing of a cephalometric radiograph taken with the lips in the resting position. Typically, the incisal margin of the

maxillary incisors should be 23 mm below the resting upper lip. When the patient smiles, the upper lip should be flush with the gingival margin.

Finally, the inclination of the maxillary occlusal plane is measured: this measurement is important because it identifies the position of the mandibular arch in relation to the maxilla. Today, any vertical discrepancies can be managed effectively with anchorage provided by orthodontic mini-screws. These screws, once inserted in the maxillary bone, provide absolute anchorage and make it possible to modify any excessive clockwise rotation of the occlusal plane and to intrude the maxillary incisors, thus correcting the overbite and vertical discrepancies, if any.

8 THE FRICTIONAL FORCE PRODUCED BY STB LINGUAL ORTHODONTIC BRACKETS BONDED TO A SIMULATED DENTAL ARCH

Akira Komori

During orthodontic treatment, the frictional force produced at the bracket–archwire interface tends to impede the expected tooth movement. Many laboratory-based studies have evaluated the frictional resistance generated between the brackets and the archwire. These studies have found that the important factors influencing the amount of friction include:

- brackets and wire materials
- surface conditions of bracket slot and archwire
- torque and angulation at the wire–bracket interface
- method of ligation
- wet or dry state of the bracket–archwire interface.

These factors are critical, in particular in lingual orthodontics, because of the narrow inter-bracket distance in these orthodontic systems.

Reduction of friction may shorten the initial treatment phase of alignment, and also the phase of sliding mechanics for space closure, when all the teeth move at the same time and the wire slides through the brackets. Low friction is very effective during the initial phase of alignment in “Social 6” lingual orthodontic treatment for a patient with crowding.

The latest generation of the lingual orthodontic bracket (STb, ORMCO, USA) has “passive ligation steps” (mesial and distal extensions of the bracket slot base), which are intended to reduce frictional forces. However, until now, it has not been clear which ligation method was most effective in combination with the passive ligation steps to achieve low friction, or the use of which size of archwire would generate the lowest friction.

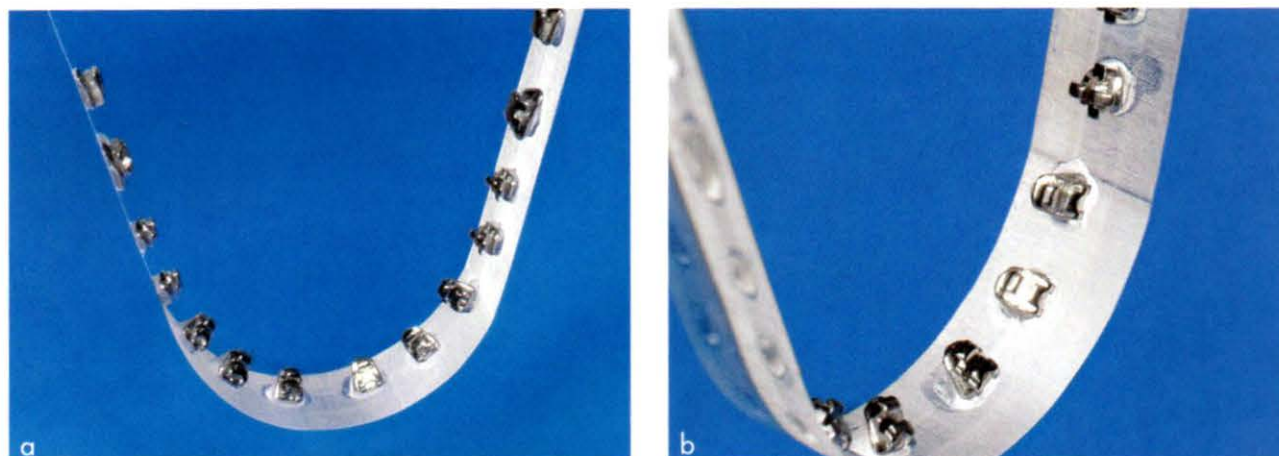
Experimental Design for the Evaluation of Friction

Information from preliminary laboratory investigations can help in selection of archwire size and methods of ligation. Therefore a laboratory study of the friction generated at the bracket–archwire interface was conducted, which involved testing of the overall friction produced by various combinations of brackets and archwires in the testing model which included 10 brackets and four tubes, that is, second molar to second molar. The arch form of the testing model also simulated the clinical situation with respect to lingual orthodontics.

STb lingual orthodontic brackets were compared with standard edgewise brackets (Mini-Diamond, ORMCO, USA) and self-ligation brackets (Damon2, ORMCO, USA). All the brackets were made of stainless steel and had a nominal slot size of 0.018×0.025 . Fourteen orthodontic brackets and tubes of each make (Table 8-1), from the maxillary right second molar to the left second molar, were bonded to an acrylic arch form with thickness of 10 mm. The arch form used for STb was the mandibular standard arch form (Figs 8-1a and 8-1b), and the maxillary OrthoForm III arch form was used for the standard edgewise brackets (Fig. 8-2) and self-ligation brackets (Fig. 8-3) (Table 8-2). Before the brackets were bonded to the acrylic arch form, they were ligated with elastic modules to a 0.018×0.025 titanium molybdenum alloy (TMA) archwire to align all bracket slots. The brackets were then bonded to the acrylic arch form with a methyl methacrylate (MMA)-based resin (Super Bond, Sun Medical, Japan). Although, in clinical practice, vertical and horizontal bends are often introduced into the arch-

Table 8-1 Orthodontic brackets used in the study.

Brackets	Site	Number of brackets	Slot size	Manufacturer
STb	From maxillary right second molar to left second molar	14	0.018 × 0.025	ORMCO, USA
Mini-Diamond	From maxillary right second molar to left second molar	14	0.018 × 0.025	ORMCO, USA
Damon2	From maxillary right second molar to left second molar	14	0.018 × 0.025	ORMCO, USA

**Fig. 8-1** (a) Test unit of STb mandibular standard arch form. (b) Close-up view of the test unit for STb brackets.

wires used in lingual orthodontics for proper alignment of teeth, the archwires used in this evaluation were not bent, in order to prevent deformation during testing. Inter-bracket distances were matched to those on dental models (D13PP-509, Nissin Dental Products, Japan).

The effects of ligation with both elastic modules and stainless steel ligature wires were also examined. Elastic modules (Dispense-a-stix Clear 0.120, TP, USA) were held with module forceps (Fig. 8-4, module pliers with groove, YDM, Japan) to prevent

squashing during ligation. Preformed stainless steel ligature wires (0.008, Tomy International, Japan) were tied with a special tying instrument (Fig. 8-5, Twist Mate, Tomy International, Japan) to ensure uniform ligation.

Five different sizes of nickel-titanium (NiTi) orthodontic wires (Tynilloy Wire, Dentsply-Sankin K.K., Japan), 0.010, 0.012, 0.014, 0.016, and 0.018, were used as they are representative of archwires used in the initial phase of alignment. For the evaluation of frictional resistance, a testing

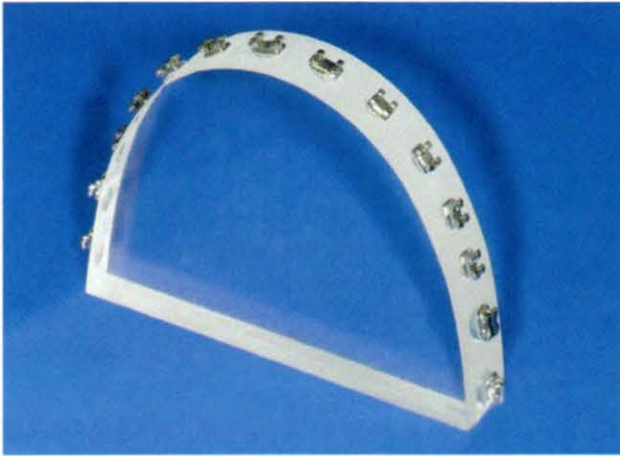


Fig. 8-2 Test unit of standard edgewise brackets maxillary OrthoForm III.



Fig. 8-3 Test unit of self-ligation brackets maxillary OrthoForm III.



Fig. 8-4 The module forceps used in the study.

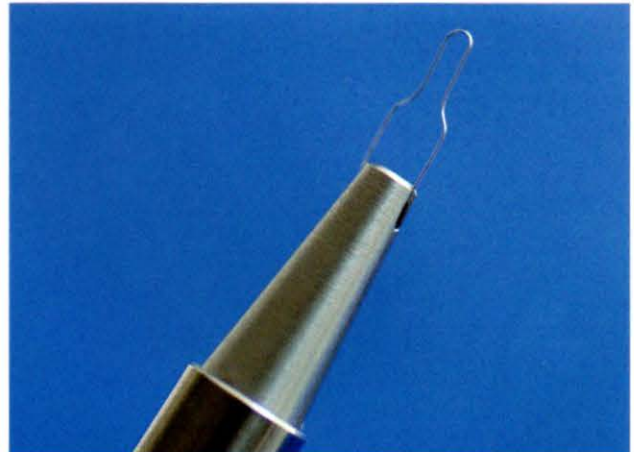


Fig. 8-5 A preformed stainless steel ligature wire held in the tying instrument.

machine (Autograph AG-I 20kNT, Shimadzu, Japan) was used. Each test unit was attached to the testing machine and pulled in a vertical direction with a cross-head speed of 1 mm/min over a 1 mm stretch of archwire (Fig. 8-6). The force required to move the archwire over a 1 mm distance was measured. Each bracket/archwire/ligation combination (Table 8-3) was tested 10 times. The highest value in each test was taken to represent the frictional resistance.

Table 8-2 Arch forms used in the study.

Brackets	Arch form	Manufacturer
STb	Mandibular standard arch form	ORMCO, USA
Mini-Diamond	Maxillary OrthoForm III	3M Unitek, USA
Damon2	Maxillary OrthoForm III	3M Unitek, USA

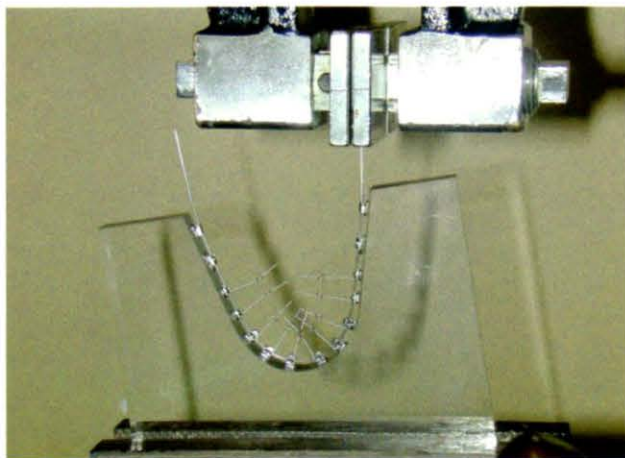


Fig. 8-6 Measurement of frictional resistance.

Frictional Properties

For all wire sizes, Damon2 produces the lowest frictional force by its passive self-ligation system, which does not press the wire against the bracket slot. The passive self-ligation system bracket is considered to be the state-of-the-art system for attaining low friction. It is noteworthy that the STb/0.010 NiTi archwire/ligature wire combination produced similar friction to the Damon2 passive self-ligation system (Fig. 8-7).

Many of the bracket/wire/ligation combinations showed that increasing archwire size is associated

Table 8-3 Bracket/wire/ligation combinations used in the study.

Group	Bracket	Wire	Method of ligation
1	STb	0.018 NiTi	Ligature wire
2	STb	0.016 NiTi	Ligature wire
3	STb	0.014 NiTi	Ligature wire
4	STb	0.012 NiTi	Ligature wire
5	STb	0.010 NiTi	Ligature wire
6	STb	0.018 NiTi	Elastic module
7	STb	0.016 NiTi	Elastic module
8	STb	0.014 NiTi	Elastic module
9	STb	0.012 NiTi	Elastic module
10	STb	0.010 NiTi	Elastic module
11	Mini-Diamond	0.018 NiTi	Ligature wire
12	Mini-Diamond	0.016 NiTi	Ligature wire
13	Mini-Diamond	0.014 NiTi	Ligature wire
14	Mini-Diamond	0.012 NiTi	Ligature wire
15	Mini-Diamond	0.010 NiTi	Ligature wire
16	Mini-Diamond	0.018 NiTi	Elastic module
17	Mini-Diamond	0.016 NiTi	Elastic module
18	Mini-Diamond	0.014 NiTi	Elastic module
19	Mini-Diamond	0.012 NiTi	Elastic module
20	Mini-Diamond	0.010 NiTi	Elastic module
21	Damon2	0.018 NiTi	Self-ligation
22	Damon2	0.016 NiTi	Self-ligation
23	Damon2	0.014 NiTi	Self-ligation
24	Damon2	0.012 NiTi	Self-ligation
25	Damon2	0.010 NiTi	Self-ligation

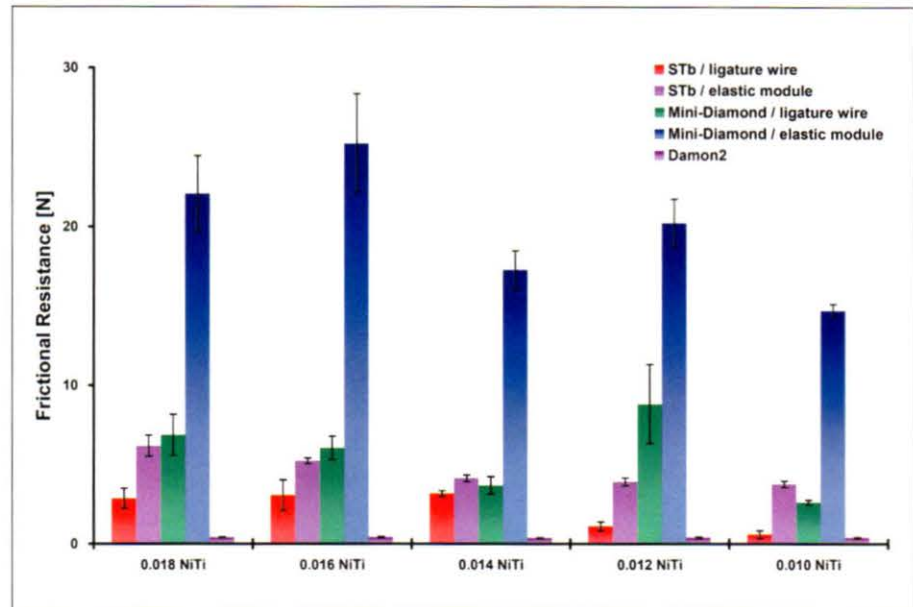


Fig. 8-7 Frictional resistance for the various bracket/wire/ligation method combinations.

with marked increases in friction. Although the Mini-Diamond brackets used in this study were labial edgewise brackets with wide inter-bracket distances, the combination of the labial edgewise bracket and the elastic module produces the highest friction for any wire size. This combination also showed two to five times higher friction than the same brackets tied with ligatures. Except for the 0.012 NiTi wire, in spite of the narrower inter-bracket distance in the STb system, the friction produced with the STb/elastic module combination was similar to that produced by the labial edgewise bracket tied with a ligature wire.

It is worth noting that STb brackets tied with elastic modules showed lower friction than the labial edgewise brackets tied with elastic modules for all wire sizes, regardless of the narrower inter-bracket distance of the STb system; this may be a result of the passive ligation steps built into the bracket design and the smaller dimensions of the STb brackets. Because labial edgewise brackets are bigger than STb brackets, when the edgewise brackets are tied with elastic modules, the modules are stretched and the archwire is strongly pressed into bracket slots. On the other hand, the elastic modules are not much stretched when put on STb brackets, because of the small size of these brackets. Therefore, the archwire is not pressed hard against the bracket

slot and friction is low. The sizes of commercially available elastic modules are 0.090, 0.110, and 0.120. In order to achieve low friction with the application of elastic modules, a larger size of elastic module should be used.

The study showed that ligature wires greatly decreased friction for all wire sizes. The combination of STb/0.010 NiTi wire/elastic module show six times higher friction than the combination of STb/0.010 NiTi wire/ligature wire. STb tied with ligature wire also produced lower friction than the labial edgewise bracket tied with elastic modules or a ligature wire for all wire sizes. The labial edgewise bracket tied with elastic modules showed five to 24 times higher friction than STb tied with ligature wire.

Clinical Implications for Use of STb Brackets

STb lingual orthodontic brackets with archwires tied with ligature wires generate much less frictional force than labial edgewise brackets regardless of the method of ligation.

A 0.010 NiTi wire would produce a light orthodontic force. With application of elastic modules, the frictional force could overcome the orthodontic

force produced by the 0.010 NiTi wire. As a result, the optimum force would not be transmitted to the tooth, and tooth movement would not be performed effectively. Therefore, during alignment, a 0.010 NiTi or 0.012 NiTi wire tied with ligature wire is recommended for effective tooth movement. The low friction produced by the STb system is very valuable in the initial phase of alignment and in cases of "Social 6" orthodontic treatment. Lingual orthodontics with STb may produce similar treatment

outcomes when compared with conventional orthodontics with labial edgewise brackets.

The narrow inter-bracket distance of the lingual bracket system is thought to induce higher friction. Therefore, the duration of lingual orthodontic treatment is expected to be longer than conventional orthodontic treatment carried out with a labial bracket system. However, the results of the preliminary investigation described in this chapter clearly dispel this myth.

9 BIOMECHANICS AND COMPARATIVE BIOMECHANICS

Biomechanics

Lingual multi-bracket appliances, besides fulfilling esthetic needs, also have a biomechanical advantage as far as the point of application of the force in relation to the center of resistance of the teeth is concerned. The center of resistance of a tooth within its alveolus is the point on the root through which the application of a horizontal force results in pure translation of the tooth, ie, without any rotational movement. The center of resistance is usually located at approximately one-third of the distance from the alveolar crest to the root apex but changes in root length or alveolar crest height will affect this.

The center of resistance of a single-rooted tooth is located almost in the middle of the root, at approximately 33% of the distance from the alveolar crest to the apex, if the periodontal support is normal. The center corresponds closely to the geometric center of the periodontally supported roots. Any variation in anatomy (such as periodontal disease or root malformation) or the location of neighboring teeth can move the center of resistance.

A maxillary molar has its center of resistance located approximately at the trifurcation in the vertical plane but more lingually in the horizontal plane. A mandibular molar has its center of resistance located approximately at the bifurcation in the vertical plane and centered buccolingually in the horizontal plane.

In the vertical plane, unlike labial brackets, the position of the lingual brackets on the maxillary incisors is closer to the long axis through the center of resistance, thus allowing easier movement whenever an occlusal force is applied. Moreover, the lingual

bracket has a position closer to the long axis, which passes through the center of resistance, than does the labial bracket. In the horizontal plane, the positioning of the lingual brackets on the maxillary incisors approximately at the long axis through the center of resistance results in a minor tendency to rotation whenever a force is applied from a mesiodistal direction, unlike in the labial technique. The same applies to the canines.

As far as the maxillary molars are concerned, the long axis passing through the center of resistance is closer to the lingual surface of the tooth. This implies that whenever an intrusive force is applied to the lingual brackets, the crowns of the teeth rotate in a lingual direction, and the opposite occurs whenever an intrusive force is applied to labial brackets – crown rotation occurs in a labial direction. As far as the mandibular molars are concerned there is no significant difference in the position of the brackets because the long axis passing through the center of resistance passes through the middle of the molars.

Another difference is because of the position of the interdental point of contact, which is more labial in the posterior segments. The greater interproximal space and larger embrasure on the lingual side cause a lingual force to be applied along the horizontal plane, generating more crown rotation with the lingual technique than would be generated by a labial force.

While evaluating the precise location of the center of resistance it is also important to consider tooth morphology, the quality of the alveolar bone and tooth inclination. Unwanted or inefficient tooth movement during orthodontic therapy results from individual variation in biological response and the improper use of forces.

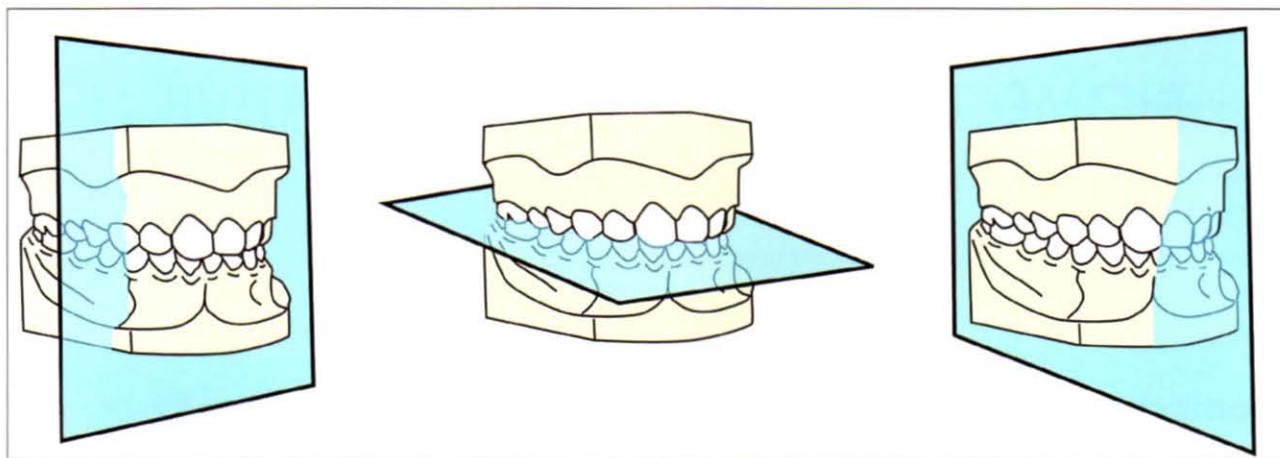


Fig. 9-1 The three planes of space: vertical, horizontal, and sagittal.

Comparative Biomechanics

It is interesting to evaluate the different forces applied to the anterior teeth by the lingual and labial techniques in the three planes of space (vertical, horizontal, and sagittal) (Fig. 9-1).

Sagittal Plane

In the sagittal plane, when the same amount of force is applied in both systems (labial and lingual), so that the intrusion force (FI) equals the retraction force (FR), the results obtained are different. In the labial system, the net force vector points directly towards the center of resistance (CR). However, the net force vector in lingual orthodontics produces a lingual tipping force and vertical bowing effect. Thus, the retractive force should be minimized during en masse retraction, and more intrusion and torque are needed to retract the anterior teeth (Figs 9-2 and 9-3).

Vertical Plane

Maxillary Arch

When using lingual mechanics, the maxillary incisors are best intruded along their long axis into the

broadest area of the alveolar process because the point of application of the force is closer to the long axis that passes through the center of resistance of the incisors.

If the root tips are forward and the crowns lingually inclined (as in a Class II, division 2 malocclusion), the intrusive force should, however, be controlled because the point of application of the force is distal to the long axis passing through the center of resistance of the incisors and this increases the lingual inclination of the crowns. In these cases it is better first to procline the crowns and then to perform the intrusion.

The following is an analysis of the effect of an intrusive force applied on the lingual and labial surface of a maxillary incisor in cases of normal, lingual, and labial inclination (Fig. 9-4).

- *Normal Inclination*

In normally inclined incisors, a vertical force of 40 g applied on the labial side, at 7 mm from the center of resistance (in the horizontal plane), produces a counter-clockwise moment of 280 gmm ($7 \text{ mm} \times 40 \text{ g} = 280 \text{ gmm}$) (Fig. 9-5). The same amount of vertical force applied on the lingual side, at 1 mm from the center of resistance (in the horizontal plane), produces a counter-clockwise moment of 40 gmm ($1 \text{ mm} \times 40 \text{ g} = 40 \text{ gmm}$) (Fig. 9-6).

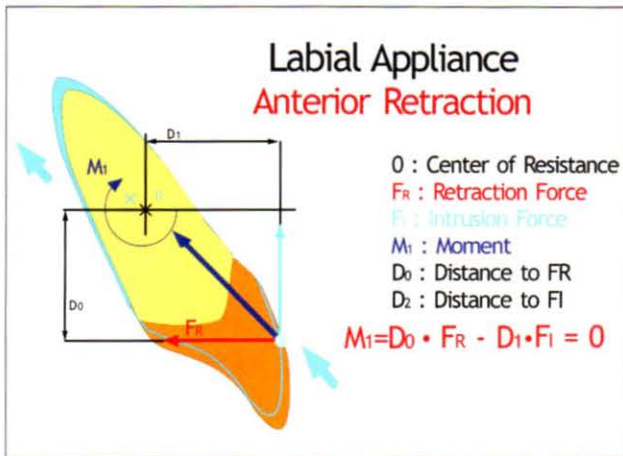


Fig. 9-2 Application of similar amounts of intrusive and retractive forces may result in intrusion with a labial appliance, owing to the differences in force direction.

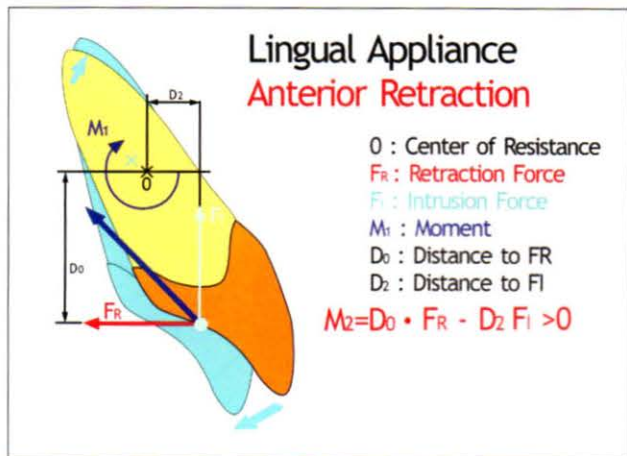


Fig. 9-3 Application of similar amounts of intrusive and retractive forces may result in a tipping force with a lingual appliance, owing to the differences in force direction.

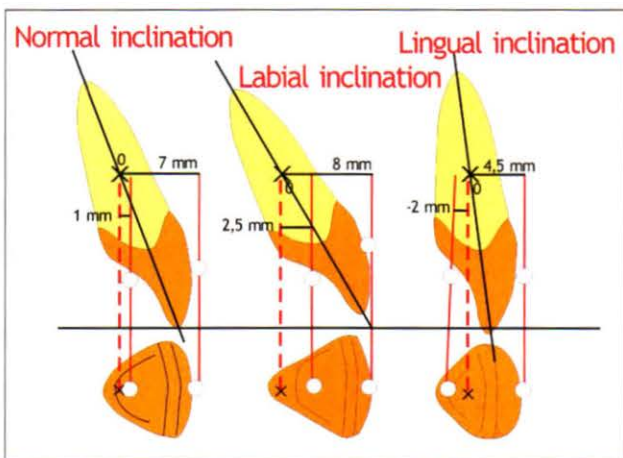


Fig. 9-4 Distance between the point of application of orthodontic forces from the center of resistance of a maxillary incisor in the vertical plane.

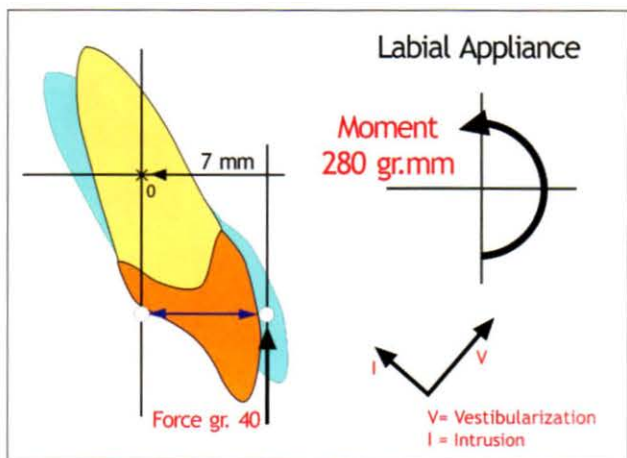


Fig. 9-5 Application of a labial force to a tooth with normal inclination.

- *Labial Inclination*

In the case of a labially inclined incisor, a vertical force of 40 g applied to the labial side, at 8 mm from the center of resistance (in the horizontal plane), produces a counter-clockwise moment of 320 gmm ($8 \text{ mm} \times 40 \text{ g} = 320 \text{ gmm}$) (Fig. 9-7).

The same amount of vertical force applied on the lingual side, at 2.5 mm from the CR (in the horizontal plane), produces a counter-clockwise moment of 100 gmm ($2.5 \text{ mm} \times 40 \text{ g} = 100 \text{ gmm}$) (Fig. 9-8).

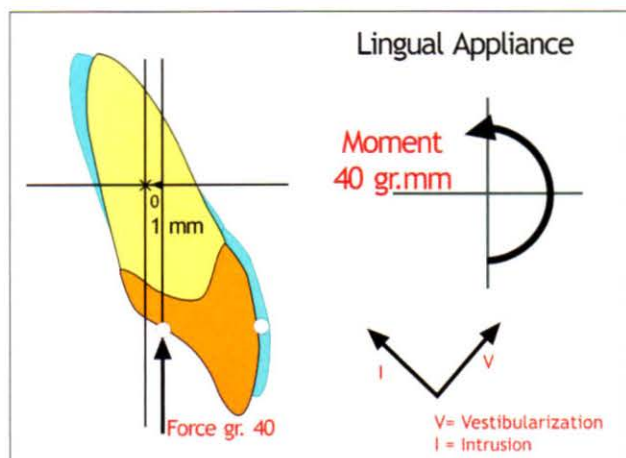


Fig. 9-6 Application of a lingual force to a tooth with normal inclination.

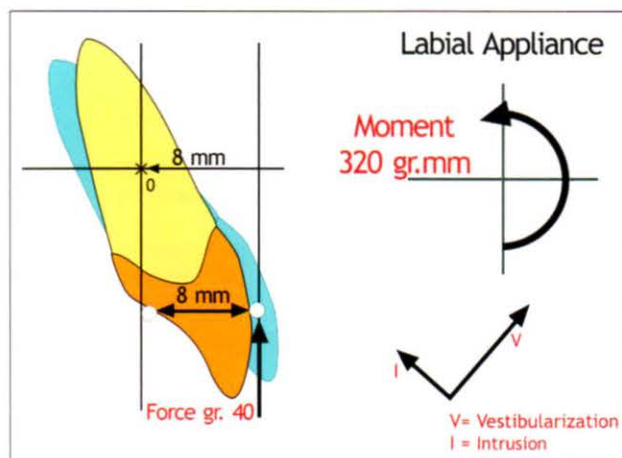


Fig. 9-7 Application of a labial force to a proclined tooth.

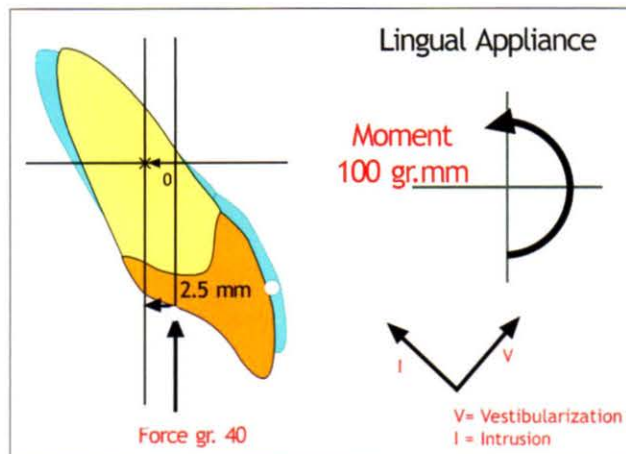


Fig. 9-8 Application of a lingual force to a proclined tooth.

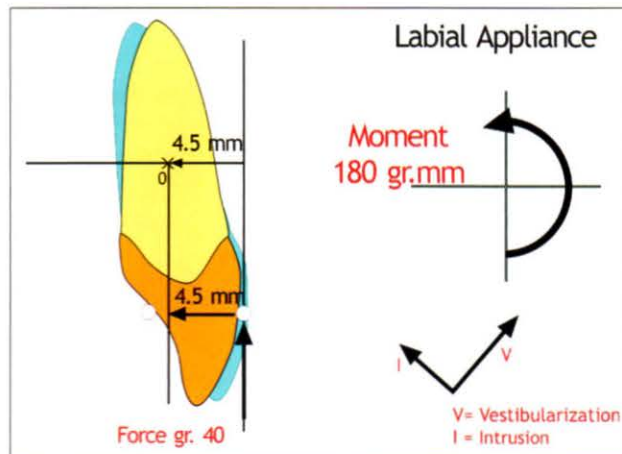


Fig. 9-9 Application of a labial force to a retroclined tooth.

• Lingual Inclination

In the case of a lingually inclined incisor, a vertical force of 40 g applied on the labial side, at 4.5 mm from the center of resistance (in the horizontal plane), produces a counter-clockwise moment of 180 gmm ($4.5 \text{ mm} \times 40 \text{ g} = 180 \text{ gmm}$) (Fig. 9-9). The same amount of vertical force applied on the lingual side, at -2 mm from the center of resistance (in the horizontal plane), produces a clockwise moment of -80 gmm ($-2 \text{ mm} \times 40 \text{ g} = -80 \text{ gmm}$) (Fig. 9-10).

Mandibular Arch

In the mandibular arch, in the case of normally inclined mandibular incisors, the lingual bracket slot is closer to the long axis passing through the center of resistance, compared with the slot of a bracket bonded on the labial side. For this reason, during the leveling phase of treatment, the lingual application of the force allows easier intrusion, that is, there is less tendency for concomitant labial tipping of the crown compared with a labially applied force (Fig.

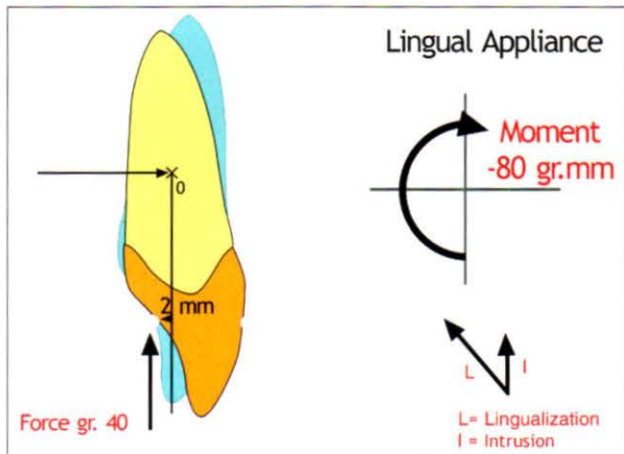


Fig. 9-10 Application of a lingual force to a retroclined tooth.

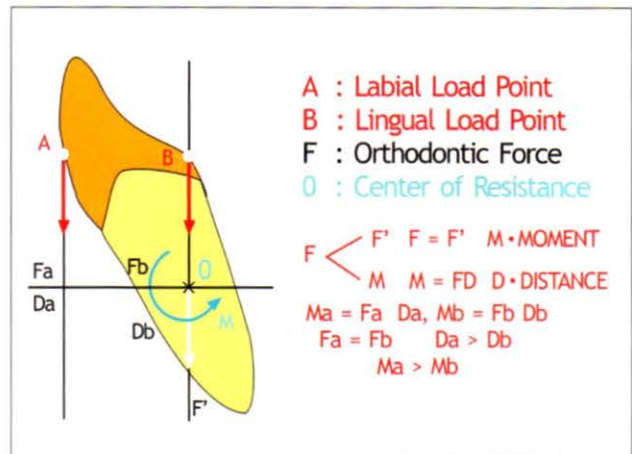


Fig. 9-11 Lingual and labial points of application of orthodontics force on a mandibular incisor.

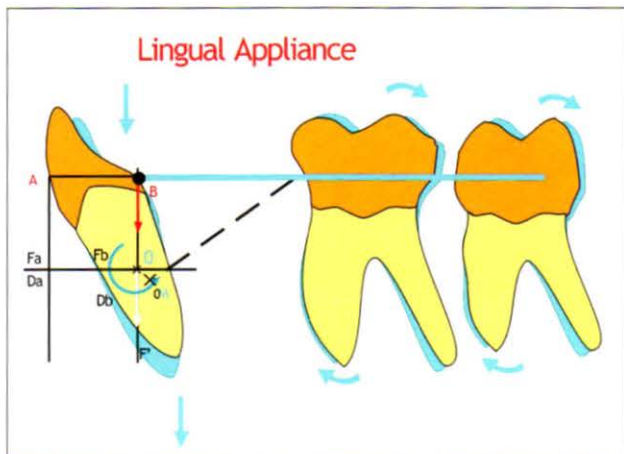


Fig. 9-12 Different effects in the sagittal plane of a lingually applied force on the mandibular arch.

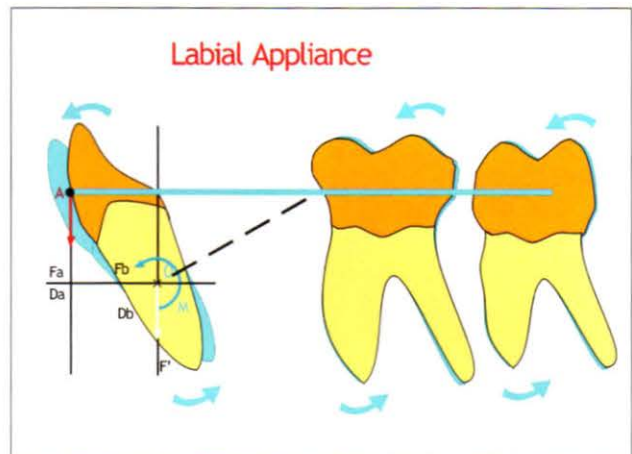


Fig. 9-13 Different effects in the sagittal plane of a labially applied force on the mandibular arch.

9-11). This movement also increases the effect of the force on the posterior segments, in the sagittal plane, compared with a labial force. In particular, this will generate more distal tipping of the mandibular molar crowns and more lingual tipping of the mandibular incisors (Figs 9-12 and 9-13).

- *Molars*

Intrusive or extrusive forces applied on the molars lead to different biomechanical effects with lingual and labial appliances. An intrusive vertical force

of 40 g applied on the labial side, at 4 mm from the center of resistance (in the horizontal plane) produces a clockwise moment of 160 gmm ($40 \text{ g} \times 4 \text{ mm} = 160 \text{ gmm}$) (Fig. 9-14). The same amount of intrusive force applied on the lingual side, at 3 mm from the center of resistance (in the horizontal plane), produces a counter-clockwise moment of 120 gmm ($3 \text{ mm} \times 40 \text{ g} = 120 \text{ gmm}$) (Fig. 9-15).

An extrusive vertical force of 40 g applied on the labial side, at 4 mm from the center of resistance (in the horizontal plane), produces a

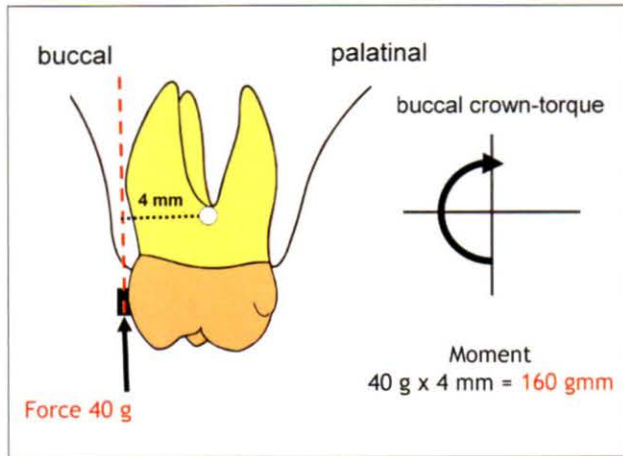


Fig. 9-14 Buccal crown torque resulting from an intrusive force applied by a labial appliance.

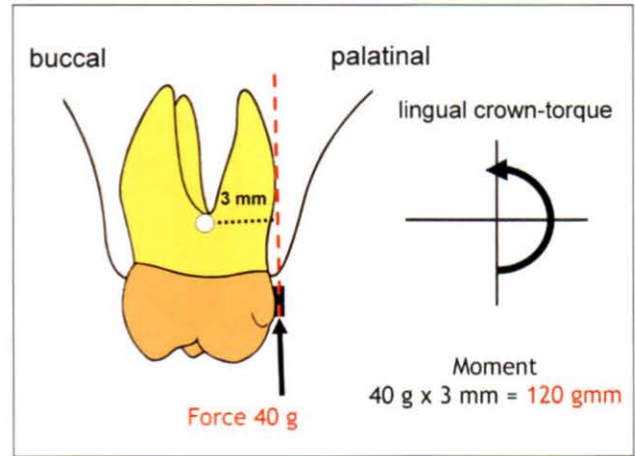


Fig. 9-15 Lingual crown torque resulting from an intrusive force applied by a lingual appliance.

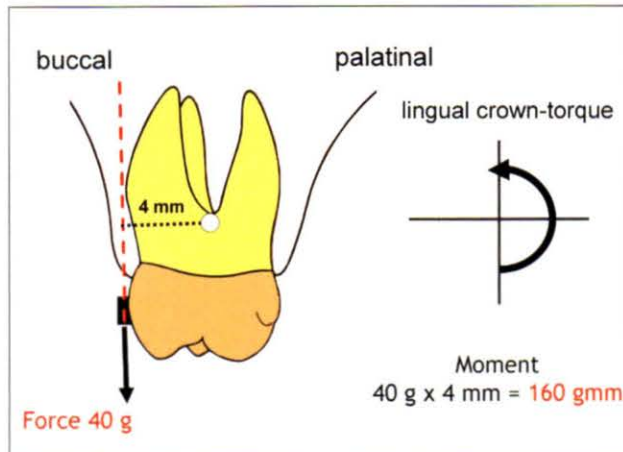


Fig. 9-16 Lingual crown torque resulting from an extrusive force applied by a labial appliance.

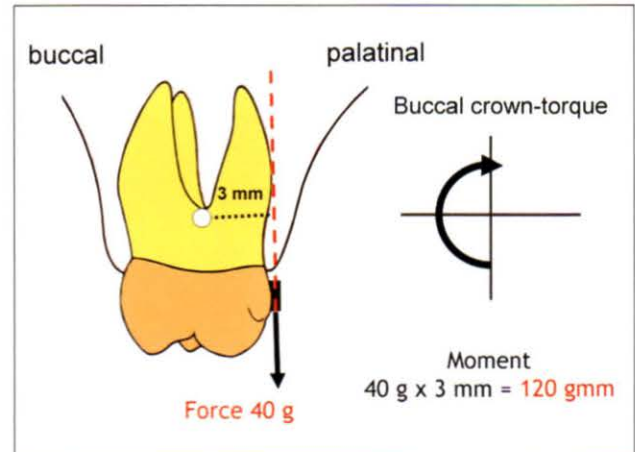


Fig. 9-17 Buccal crown torque resulting from an extrusive force applied by a lingual appliance.

counter-clockwise moment of 160 gmm ($40 \text{ g} \times 4 \text{ mm} = 160 \text{ gmm}$) (Fig. 9-16). The same amount of an extrusive force applied on the lingual side, at 3 mm from the center of resistance (in the horizontal plane), produces a clockwise moment of 120 gmm ($3 \text{ mm} \times 40 \text{ g} = 120 \text{ gmm}$) (Fig. 9-17).

Horizontal Plane (Occlusal Plane)

The teeth are positioned along geometrically elliptical arches in the occlusal plane (parallel to

the horizontal plane). In the occlusal plane, the inter-bracket distance in lingual orthodontics is shorter than in labial orthodontics. For this reason, the archwire stiffness increases with the lingual technique and there is less rotational moment than with the labial technique.

Moreover, in lingual orthodontics, the point of application of the force is closer to the long axis of the tooth. These anatomical factors raise important biomechanical considerations:

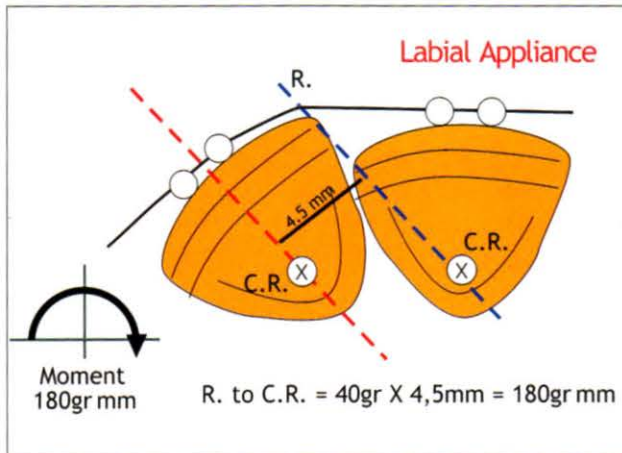


Fig. 9-18 Inter-bracket distance and the effect of a labial force in the horizontal plane.

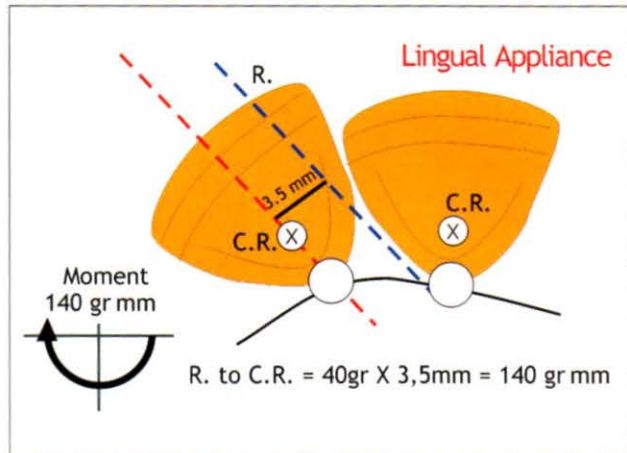


Fig. 9-19 Inter-bracket distance and the effect of a lingual rotational force in the horizontal plane.

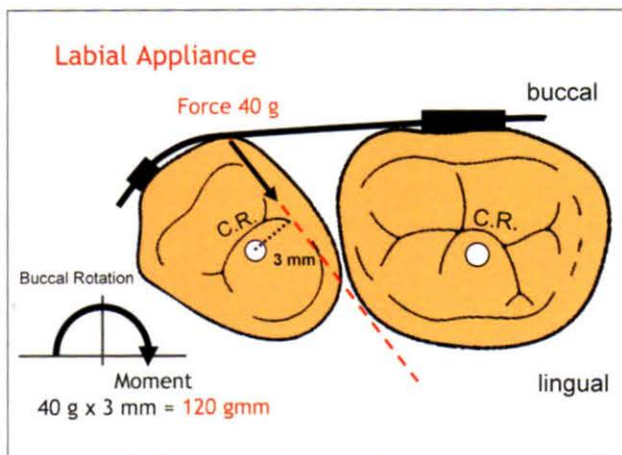


Fig. 9-20 Adequate derotational moment with a labial appliance.

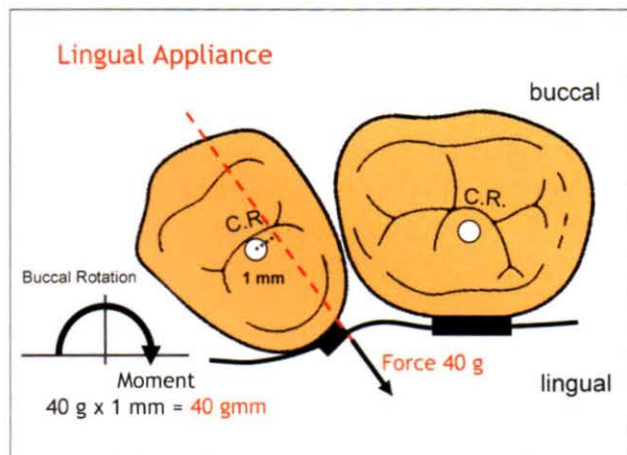


Fig. 9-21 Small derotational moment with a lingual appliance.

- It is more difficult to have an efficient coupling of forces on the lingual side during rotational movement.
- The rotational moment is less with force application on the lingual side than on the labial side.
- In cases of crowding, it is more difficult to engage the archwire in lingual brackets than in labial brackets, so a more resilient archwire is required (Figs 9-18 and 9-19).

Derotating forces applied to the premolars by the archwire are more effective in labial appliances

than in lingual appliances due to different biomechanical efficiency. A derotating horizontal force of 40 g applied by the archwire on the labial side, at 3 mm from the center of resistance (in the horizontal plane), produces a clockwise moment of 120 gmm ($40 \text{ g} \times 3 \text{ mm} = 120 \text{ gmm}$). The same amount of derotating horizontal force applied on the lingual side, just at 1 mm from the center of resistance (in the horizontal plane), produces a clockwise moment of only 40 gmm ($1 \text{ mm} \times 40 \text{ g} = 40 \text{ gmm}$) (Figs 9-20 and 9-21).

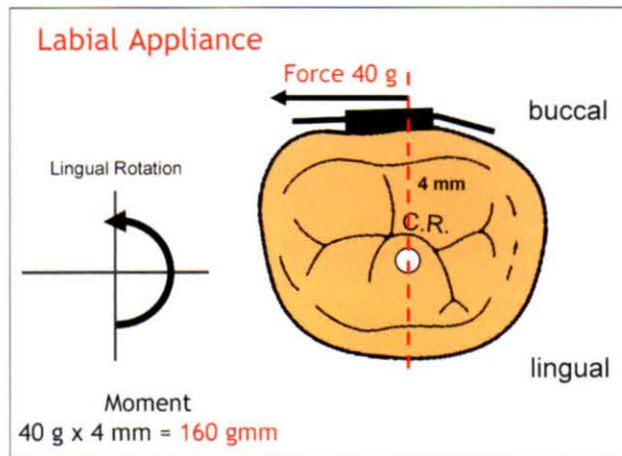


Fig. 9-22 Lingual rotation of molars during retraction of the anterior teeth using a labial appliance leads to loss of anchorage.

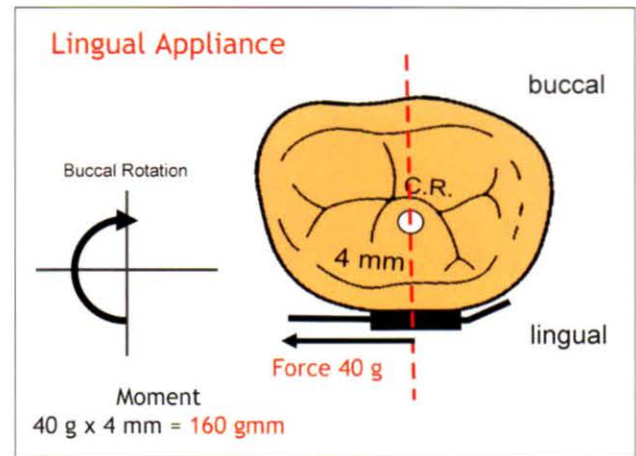


Fig. 9-23 Buccal rotation of molars during retraction of the anterior teeth using a lingual appliance leads to preservation of anchorage.

During retraction of the anterior teeth, a sagittal force is applied on the molars in an anterior direction, which has different effects on the anchorage. A horizontal force of 40 g in the anterior direction applied by the archwire on the labial side during retraction of the anterior teeth, at 4 mm from the center of resistance (in the horizontal plane), pro-

duces a counter-clockwise moment of 160 gmm ($40 \text{ g} \times 4 \text{ mm} = 160 \text{ gmm}$) (Fig. 9-22). The same amount of horizontal force in an anterior direction applied on the lingual side, at 4 mm from the center of resistance (in the horizontal plane), produces a clockwise moment of 160 gmm ($4 \text{ mm} \times 40 \text{ g} = 160 \text{ gmm}$) (Fig. 9-23).

10 IMPROVEMENTS IN LABORATORY PROCEDURES

with Didier Fillion

Introduction

The widespread use of edgewise or straight wire appliances makes it imperative that brackets are positioned with 100% accuracy in order to exploit fully the built-in prescriptions as the patient progresses through the stages of orthodontic treatment. Years of practice in using preadjusted edgewise brackets on lingual surfaces with the Kurz-ORMCO method have provided much insight into lingual dental morphology, confirming what the abundant data on bonding brackets to the labial surface of teeth had already demonstrated: that tooth shape can alter the amount of built-in angulation and inclination (tip and torque) in the bracket slots or bases to the extent of significantly affecting appliance control and treatment outcome. There is just too much variation and irregularity in the lingual anatomy of the human dentition for “mass-

produced” brackets with standard tip, torque, and rotation control values to accommodate the majority of cases (Figs 10-1 to 10-3). Owing to this problem many lingual specialists have recognized the need for greater accuracy in indirect bonding techniques, and have sought to improve the laboratory process in an attempt to achieve better results in the clinic.

In the last two decades of the twentieth century, lingual orthodontics saw the development and application of two major techniques, the Torque Angulation Reference Guide (TARG) and the Custom Lingual Appliance Set-up Service (CLASS). The search for improved bracket positioning in the laboratory has resulted in many modifications or combinations of techniques. The most interesting recent advances are the Lingual Straight Wire set-up laboratory procedure and the ORAPIX computerized set-up system.

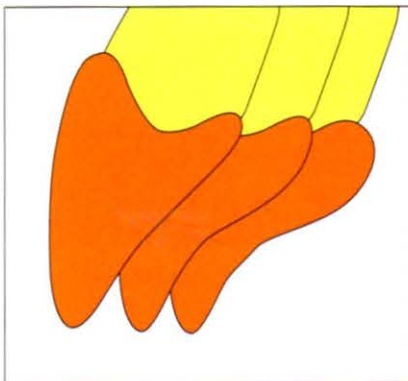


Fig. 10-1 Illustration of the wide range of inter-individual variation in lingual tooth surface morphology.

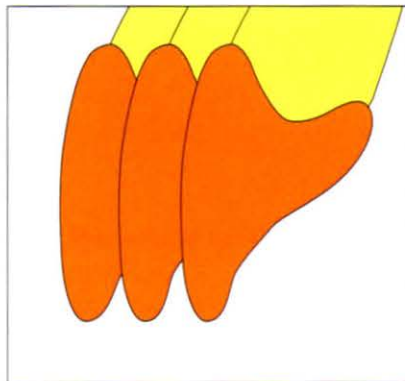


Fig. 10-2 There is less inter-individual variation in labial tooth surface morphology compared with the lingual surfaces (see Fig. 10-1).

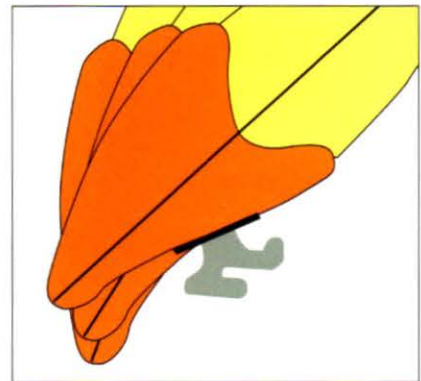
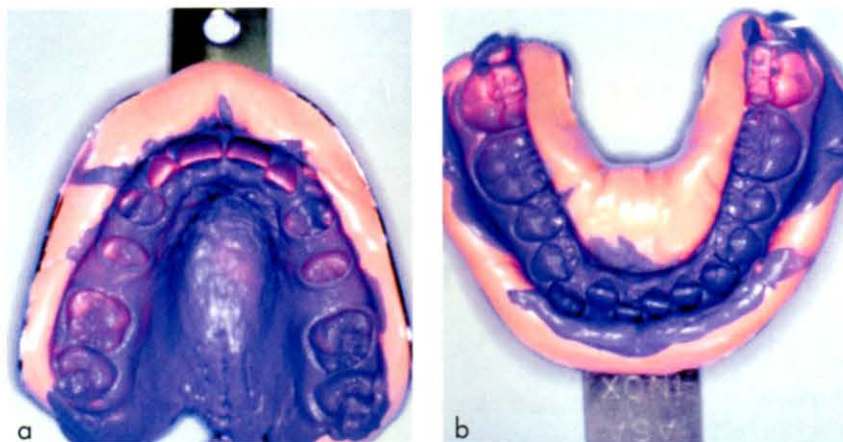


Fig. 10-3 Lingual brackets bonded at the same height on morphologically different lingual surfaces express different torque values.



Figs 10-4a,b High-quality upper and mandibular impressions.



Figs 10-5a,b Maxillary and mandibular models reduced to a height of 8 mm.

Constructing the Set-up: Step-by-step Procedure

This section describes the process of set-up preparation, bracket placement, ideal arch bending, and construction of transfer trays that delivers the orthodontist's prescription into the appliance, including the addition of any necessary overcorrections.

Impressions

First and foremost, it is essential that the impressions should be as accurate as possible, which is why the best materials such as high-quality alginate or silicone should be used (Figs 10-4a and 10-4b). Not only is the entire accuracy of the bonding procedure dependent on the quality of the models, but there is also a direct influence on the amount of compensating wire bending required later.

Models

The models should be poured with hard plaster and then duplicated so as to have a reference malocclusion cast available during the set-up process. The models are first reduced to a height of 8 mm from the base to the gingival margin (Figs 10-5a and 10-5b). The technician then makes retention grooves on the bottom of both the maxillary and mandibular models in the region of the first and second molars (Fig. 10-6), to allow better repositioning of the teeth after they have been sectioned individually. The bottom of each model is then coated with a separating medium and a complementary base constructed. Finally, the models are trimmed all around so that there is no step between the model and the base (Fig. 10-7).

The finished models are mounted on an articulator with the help of a facebow. If there is a centric

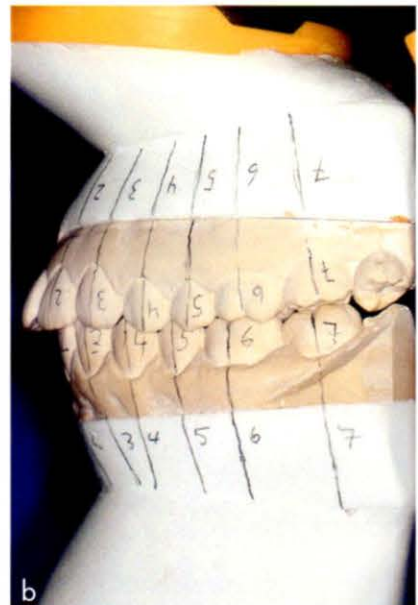
Fig. 10-6 (left) Models with grooves for retention.



Fig. 10-7 (right) Maxillary and mandibular models with new bases.



Figs 10-8a,b Models in articulator with the long axes marked on the right and left sides.



relation/centric occlusion discrepancy exceeding 1 mm, the models should be mounted in centric relation. Any articulator is suitable provided that it has a hinge axis and it can be adjusted to reproduce immediate Bennett side shift, progressive Bennett side shift, and the protrusive path.

Marking the Long Axis of the Teeth

The long axis of all the teeth are marked on the lingual and buccal surfaces, and the lines extended onto the bases, according to Andrews' method. This record of the original positions of the teeth on the model facilitates monitoring of the changes made in the set-up (Figs 10-8a and 10-8b).



Fig. 10-9 Setting the molar segments and waxing up the anterior segment.

The teeth to be repositioned must be numbered with a pencil for identification. The technician should confer with the orthodontist in advance to check whether a tooth movement is realistic or not. Marking of the correct midlines, both maxillary and mandibular, is another useful reference, and the technician must be informed of any anticipated midline changes. Panoramic radiographs are useful for establishing root position.

Model Trimming

All the teeth from second premolar to second premolar in the mandibular arch are sawn off the model with a fine ribbon saw blade. Avoid sawing the contact point, which should be broken as naturally as possible. Trim individual teeth proximally, being careful not to damage the contact points: this proximal trimming is particularly important when correcting rotated teeth. The base of each tooth segment should be reduced by 4 to 5 mm. The molars are not cut until later, as the vertical and sagittal dimensions of these segments must be maintained. After trimming the mesial side of the first molars below the contact point, all four molar segments are repositioned on the models in the articulator and fixed



Fig. 10-10 Checking the occlusion on the articulator.

with a small amount of wax. Finally, the anterior part of the models is coated with a thin layer of wax (Fig. 10-9).

Setting up the Mandibular Arch

After repositioning all molar segments and checking the occlusion on the articulator (Fig. 10-10), the technician can start to construct the actual setup. The first step involves positioning of the mandibular incisors, bearing in mind that all cephalometric evidence seems to point to the fact that ideal IMPA is as near as possible to 90 degrees. Having carefully set the midlines, the technician can proceed with evaluation and setting of tip and torque values using the TAD device according to the orthodontist's prescription.

After setting the mandibular incisors (Figs 10-11a and 10-11b), the mandibular canines are positioned. Care must be taken to ensure that the intercanine width is maintained, and that the labial surfaces of the canines are 90 degrees to the sagittal plane (to avoid root impaction in the lingual or labial cortical bone). Angulation will depend on the treatment objectives. Only when the anterior segment is finished are the molars set in accordance with the leveled occlusal plane.

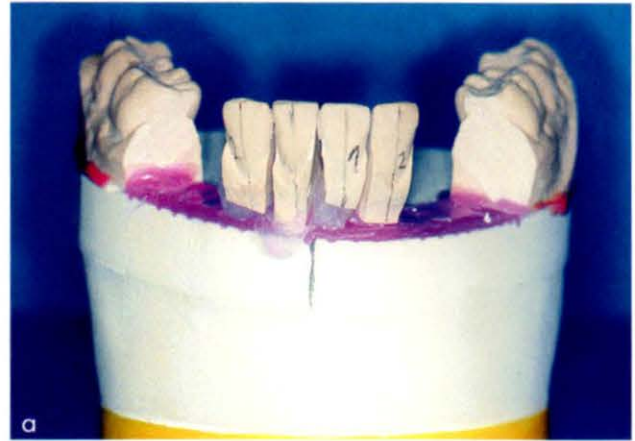
The second premolar set-up depends on arch length discrepancy, and in cases with crowding the second premolars should not be set at this point. Finally, the molar segments are removed and trimmed in the same way as the other teeth to complete the mandibular arch set-up. Above all, it is important to maintain intermolar width, flatten the curve of Spee and have only a very mild Wilson's curve.

Setting Up the Maxillary Arch

The maxillary teeth are now cut off and set in ideal relationship to the mandibular teeth. Any discrepancies such as microdontic laterals or first premolars wider than second premolars should be checked and quantified to optimize the maxillary/mandibular tooth relationships (Fig. 10-12).

Maxillary anterior torque is determined by the treatment plan, using the cephalometric analysis as a reference before assessing and setting the teeth. A general guide is to have an interincisal angle of 125 ± 5 degrees. A key point when setting the maxillary anterior teeth is that they must not create interferences during protrusion, with the protrusive path determined by the patient's glenoid fossae. The role of the protrusive path in setting the maxillary anterior teeth is twofold: it determines the torque of the lingual surfaces of the maxillary anterior teeth and also the appropriate overjet/overbite relationship as related to the occlusal plane. If the protrusive path is overly steep in relation to the occlusal plane, the overbite needs to be reduced, and vice versa. The average protrusive path value is estimated to be 40 degrees, and this should be set in the articulator. The maxillary lateral incisors must be set so that during protrusive movements the mandibular lateral incisors and canines just gently touch them, with the lingual slope of the maxillary teeth providing a guide for smooth gliding of the mandibular teeth, with no abrupt movements.

Prior to setting the maxillary posterior teeth it is important to analyze the buccal and lingual cusps of the premolars and molars. Normally, the lingual and buccal cusps of the first premolars are equal in length, while the lingual cusp of the second



Figs 10-11a,b Setting the mandibular incisors.

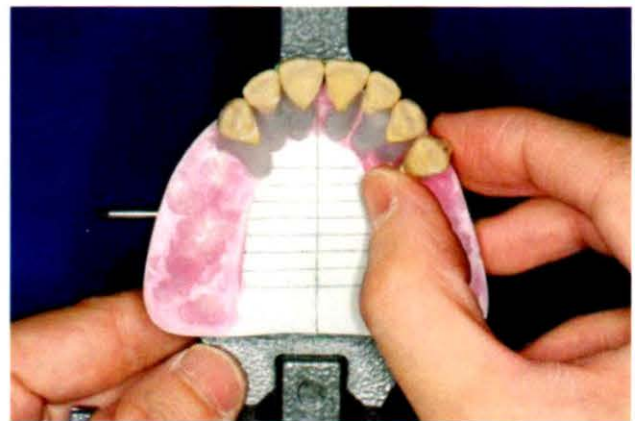
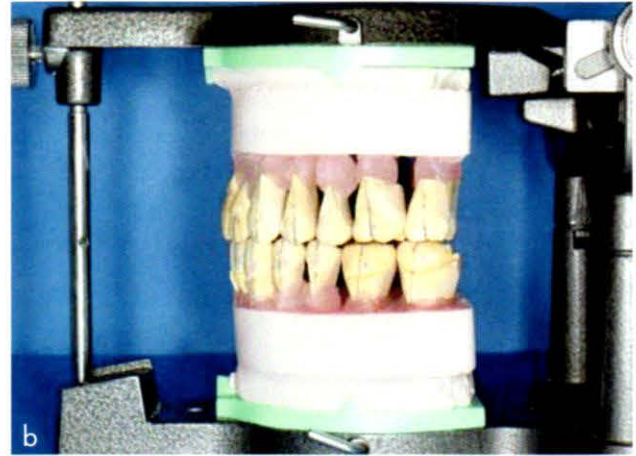
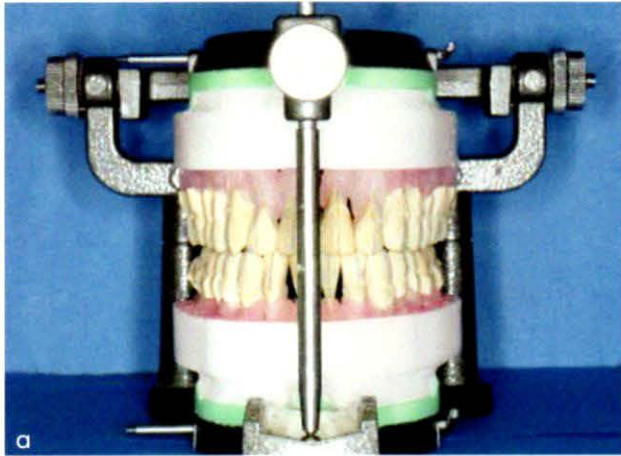


Fig. 10-12 Setting the maxillary incisors.

premolar is higher than the buccal. Looking at the first molar and second premolar, the former's lingual cusp is higher than the latter's. In addition, the second molar's lingual cusp is higher than its buccal cusp, while the first molar's lingual cusp is



Figs 10-13a,b Frontal and lateral views of the complete set-up.

lower than that of the second molar. From these anatomical considerations we can conclude that the longer lingual cusps must not be set too low, as this could cause interferences on the balancing side during protrusive movements. On the working side there should be no contact with the posterior teeth either buccally or lingually. Canine or group function should be established. On the balancing side there should be absolutely no contact at all between the canines during functional movement. The amount of overbite is adequate when all the posterior teeth are clear of contact in the protrusive position. If the clearance is too abrupt or too heavy, the overbite can be reduced. If there are protrusive interferences among the posterior teeth, the overbite must be increased.

The maxillary and mandibular models can now be mounted onto a dual cast, which should articulate fully. Only when there is maximum intercuspation of all posterior teeth with no premature contacts, sliding, or skidding of the mandible into eccentric positions, and the jaws close into satisfactory centric occlusion, can the set-up be considered ready (Figs 10-13a and 10-13b).

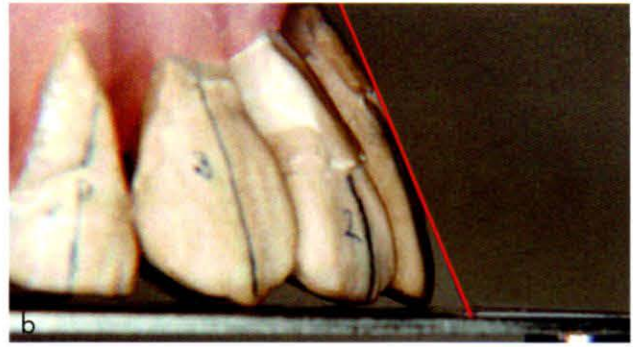
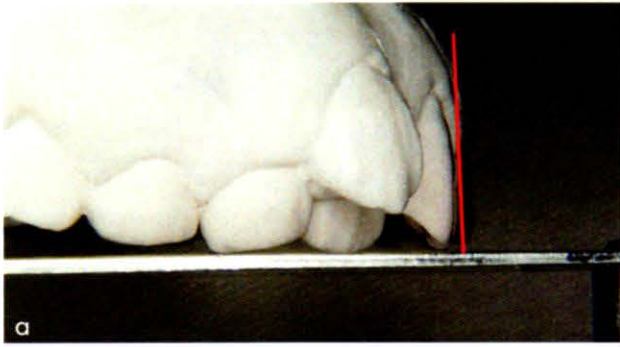
Overcorrection in Extraction Cases

Extraction cases will require overcorrection: in some patients this is done on the set-up models, while in others, brackets with built in overcorrection may be

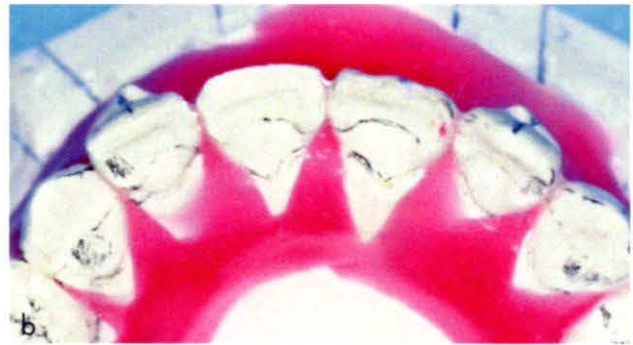
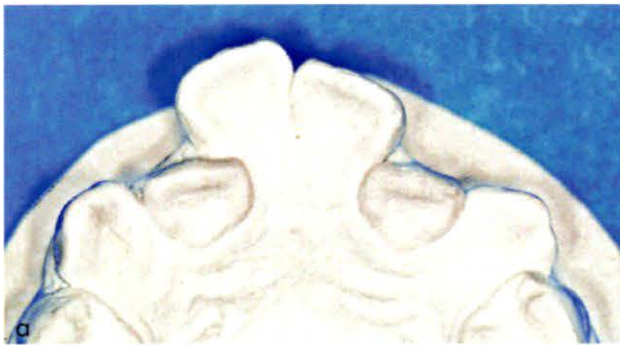
chosen. For maximal correction and root paralleling, to reduce the chance of relapse and compensating for mechanical problems, it is necessary to add torque, in-out, and overangulation to each tooth in the set-up, which also reduces the need for adding bends in the wires.

Before assessing the overcorrections required, it is important to consider three factors that can affect the amount of overcorrection: bracket slot precision, archwire size, and the wire-slot relationship. Bracket slot precision is a fundamental point (see Chapter 4), and for this reason STb brackets are constructed with very high accuracy, that is, less than 2 degrees play with a full size archwire (0.018 × 0.025). Furthermore, the size of the archwire, full or undersized, used during the “en masse retraction” stage influences the amount of overcorrection.

Previous set-up procedures relied on the clinician’s clinical and artistic expertise to move the teeth within reason into the desired position, even going to the extent of personalizing each case with a distinctive touch. Using the TAD device, tip and torque overcorrections can be calculated and executed in a way that takes the guesswork out of it. Clearly, this does not imply total depersonalization: once the set-up is ready – and even more so when it includes overcorrections – only the orthodontist can control the process. Not only must the clinician monitor and guide arch form and tooth position corrections, but he or she can and should also make a personal evaluation in relation to each individual patient. They will be



Figs 10-14a,b Increasing lingual root torque for upper anterior teeth: lingual root torque is incorporated to resist lingual tipping of the crowns during en-mass retraction in first premolar extraction cases.



Figs 10-15a,b Increasing lingual root torque for upper lateral incisors: lingual root torque is incorporated to resist lingual tipping of the crowns when the maxillary lateral incisors are in linguoversion.

the one making the final decisions regarding torque, tip, and in-out, so as to ensure that the two arches are kept coordinated. Overcorrections that depart from an ideal set-up will give the lingual archwire sufficient initial force to ensure that the appliance allows expression of correct torque and tip.

Torque

As a general rule Class II patients treated with premolar extraction require extra anterior labial crown torque to their maxillary incisors (+5 degrees beyond the desired outcome using 0.017 × 0.025 wire size) and additional torque on the mandibular anterior teeth (+5 degrees), to compensate for retroclination during space closure mechanics.

Maxillary and mandibular canines need positive extra torque (0 to +2 degrees) in order to avoid cortical bone impaction (Figs 10-14 to 10-16).

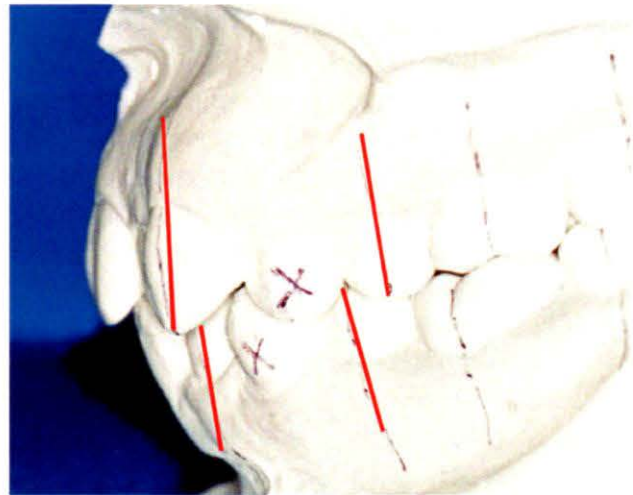
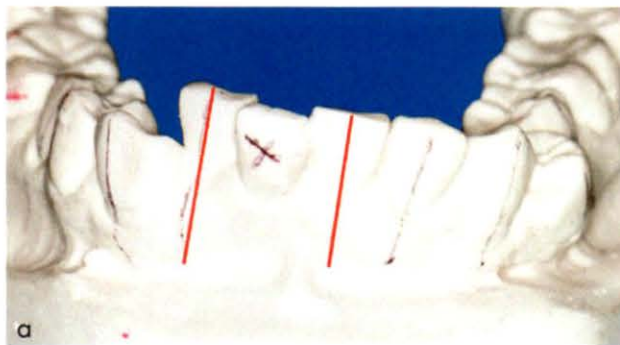


Fig. 10-16 Increasing lingual root torque for upper canines: lingual root torque is incorporated to resist lingual tipping of the crowns when the canines are lingually tipped.



Fig. 10-17 Overangulating maxillary and mandibular canines and second premolars: the canines are tipped mesially and second premolars distally in a first premolar extraction case.



Figs 10-18a,b Overangulating the mandibular incisors: adding angulation to resist tipping into the extraction site in a case finished with three incisors.

Tip (Angulation)

Angulation of teeth adjacent to the extraction site also calls for overcorrection (Fig. 10-17). Additional angulation for distal root tipping is needed for the maxillary canines (5 to 6 degrees) to facilitate the distal bodily movement during space closure. The maxillary second premolars need mesial root tipping by 5 to 6 degrees and the first and second molars require tipping backward by 3 to 5 degrees in order to increase posterior anchorage, to prevent the vertical bowing effect during space closure mechanics, and to achieve root paralleling.

Generally in extraction cases we also alter the tip of the anterior teeth to ensure an outcome with proper root paralleling: we add 2 degrees distal root tip to the maxillary central incisors and 2 to 4 degrees distal root tip to the lateral incisors (Figs 10-18a and 10-18b).

Rotation

Excessively rotated teeth must be overcorrected in the set-up to allow the lingual bracket to force the tooth in its correct position, with a range of 3 to 5 degrees overcorrection.

Overbite

Ideal overbite is generally programmed in the set-up, averaging 1 to 2 mm, with variation according to the patient's pretreatment overbite: this correction value will increase or decrease for open bite or deep bite, respectively. Where there is crossbite of the maxillary laterals (a common trend in Asian patients) all four incisors are set on the same vertical level in order to prevent relapse.

Overcorrection of the occlusal plane may be necessary in cases of extrusion or intrusion of specific teeth. In general the maxillary occlusal plane is largely dictated by the mandibular arch and the gnathological fit of the teeth.

Overjet

Sometimes there is contact between the mandibular incisal edges and the maxillary brackets. This tends to procline the maxillary incisors and intrude the mandibular incisors, thus increasing overjet. Although this fact should be recognized, it does not directly affect the set-up and must be managed with bracket placement, the mechanics, and bite plane control.

Lingual Straight Wire Laboratory Procedure

Dr. Komori introduced improvements in the lingual laboratory procedure and Dr. Takemoto and Dr. Scuzo adapted it for the lingual straight wire system.

Step-by-step Procedure

The set-up model is prepared, including some over-correction, keeping in mind that the quality of the model will affect both the procedure and the treatment results.

Maxillary Arch

Take the vertical midpoints of the molar clinical crowns as reference, draw a horizontal line through them and then extend it to include the anterior teeth. Check that the line is at two-thirds of the clinical height on the upper anterior teeth, but there is a minimum clearance of 1.5 mm from the gingival margin.

Mandibular Arch

In most cases, the height of the clinical crown of the first premolar is critical. The middle of this crown is our reference point (in extraction cases we use the second premolar). When a line drawn through this point is extended to include the anterior teeth it should pass through the middle of the clinical crowns at a distance of 1.5 mm from the gingival margin. For a premolar with a very short clinical crown, a vertical step-down can be added to the

archwire to compensate for it or, alternatively, the lingual cusp of the first mandibular premolar may be built up with composite, since this is the only cusp that does not occlude with its antagonist.

Using a Full Size Archwire

Adapt a full size stainless steel preformed lingual straight wire (0.018 × 0.025) to the individualized set-up arch form. To correctly estimate the distance between the wire and the lingual surface of the teeth it is helpful to engage all the brackets on the archwire.

It is important to control the wire while making bends to avoid introducing any undesired torque in any part of the wire.

Once the ideal maxillary and mandibular archwires have been separately prepared, the two wires must be coordinated in the predetermined position and then checked on the set-up.

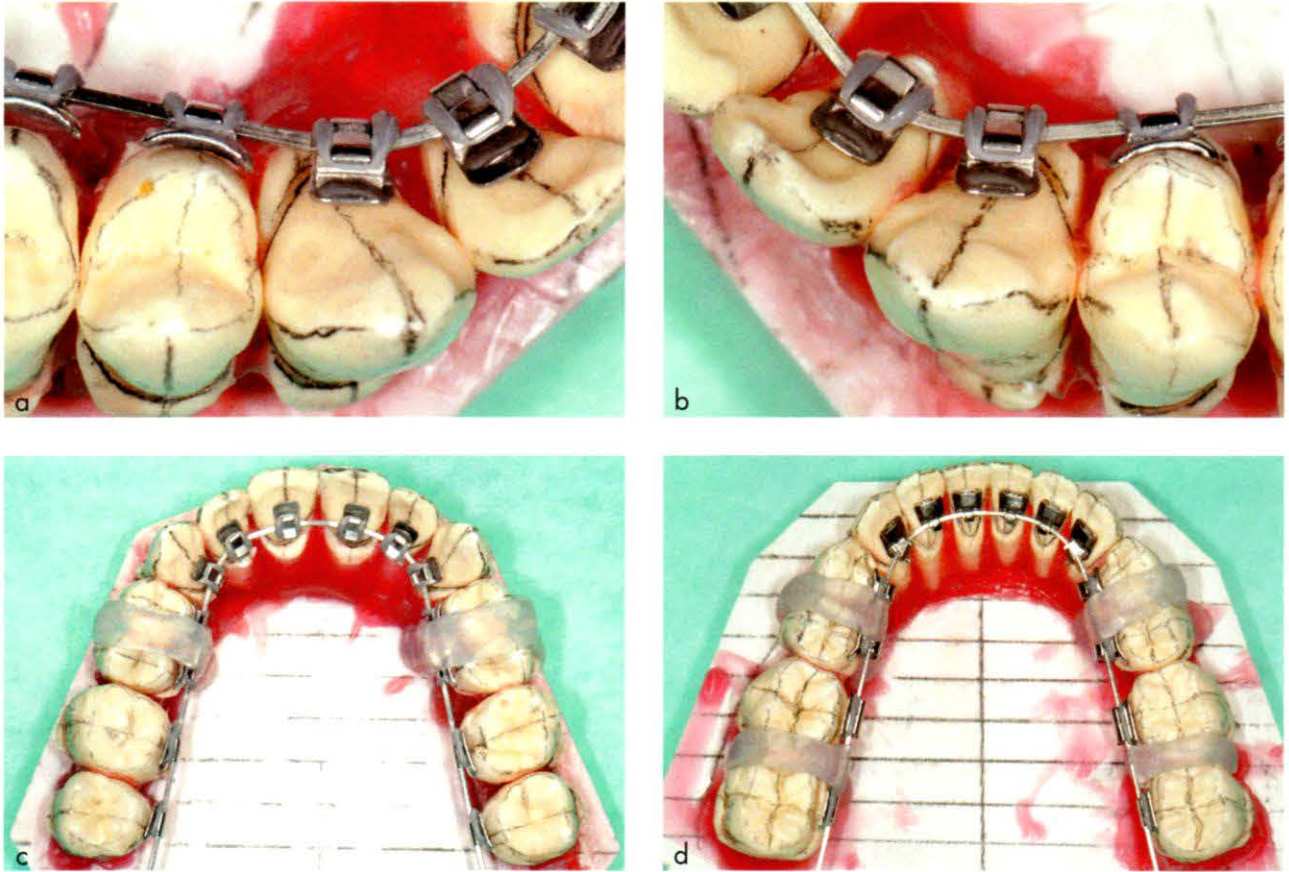
Bracket Placement

Place the wire, complete with the brackets, on the set-up, checking that each bracket is properly centered on its tooth and that there is the smallest possible gap between the mesh pad and the tooth's lingual surface. The upper and lower cuspid brackets will have a distal offset position owing to the lingual straight wire approach (Figs 10-19a and 10-19b).

At times it may be necessary to make adjustments to the mesh pad by bending it or grinding it. Check the posterior teeth in the same way and fix the archwire on the set-up model with orthodontic wax (Figs 10-19c and 10-19d).

3D Archwire

After stabilizing the archwire parallel to the occlusal plane, three reference points are marked on it – one in the midline and two posteriorly between the second premolars and first molars – with glass ionomer cement. These points make it possible to duplicate the exact position of the wire on the set-up and consequently the bracket position, with the 3D



Figs 10-19 (a,b) The upper and lower cuspid brackets have a distal offset position owing to the lingual straight wire approach. (c,d) Archwires fixed to the maxillary and mandibular models with wax.

reference archwire acting as a rebonding reference (Figs 10-20a and 10-20b).

Customizing the Bracket Base

Owing to the lingual tooth morphology, there are small spaces between the bracket base and the tooth surface. Apply enough light-cure adhesive paste with fluoride onto the mesh pads of all the brackets to fill in the gaps and to extend the resin pad onto the lingual surface of the teeth in accordance with the Komori system (see Chapter 17 for details). The excess composite must be removed, especially on the gingival side, before light curing (Figs 10-21 to 10-24).

Rebonding or Resetting of the Teeth

Accurate rebonding has been always a weak point of lingual orthodontics. The main reason for this is that all lingual techniques use a flexible inner tray made from pressure vinyl or silicone. The flexible material allows initial seating of the trays, following which pressure is applied before setting the brackets. The disadvantage of using these trays for initial bonding is that they cannot be used for rebonding. This is because the tray no longer fits the patient's mouth as a result of tooth movement. So it has to be sectioned into single-tooth trays, which leads to loss of the precise reference points for bracket position in the three planes of space. The new bracket-tray system eliminates this drawback. Another advantage of this procedure is the possibility to re-evaluate and/or reset the position (torque and tip) of a single



Figs 10-20a,b Creating the three reference points with light-cured glass ionomer.

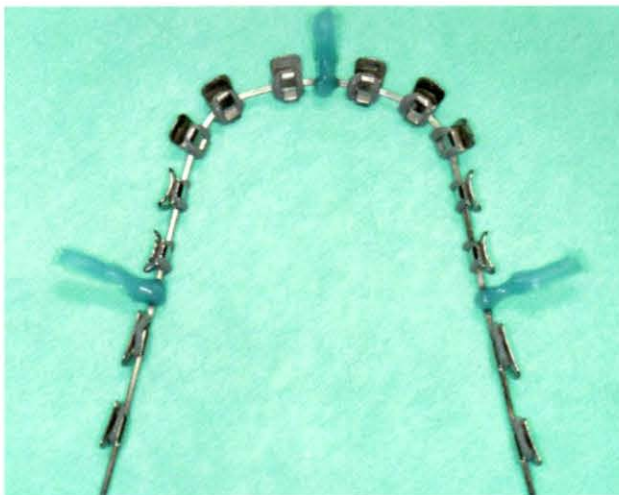


Fig. 10-21 Brackets tied with elastic ligatures.

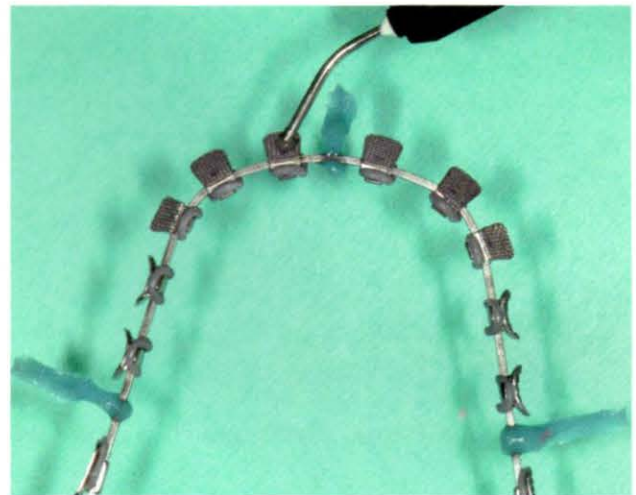


Fig. 10-22 Applying resin composite material onto the mesh pads.



Figs 10-23 Placing the archwire on the model, removing excess resin, and curing.

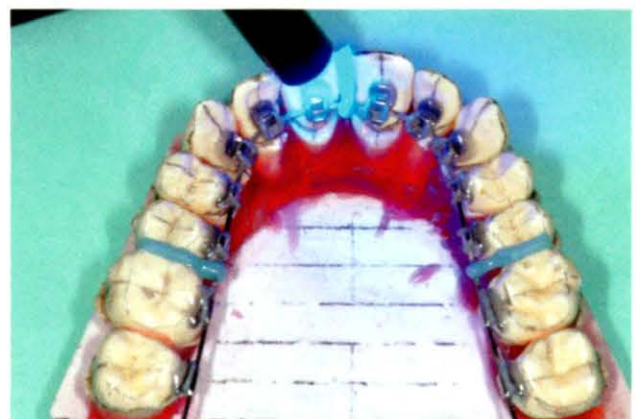


Fig. 10-24 Thermo glue gun.



Figs 10-25a,b Making individual trays.



Figs 10-26a,b The glue/resin core fitted on the teeth.



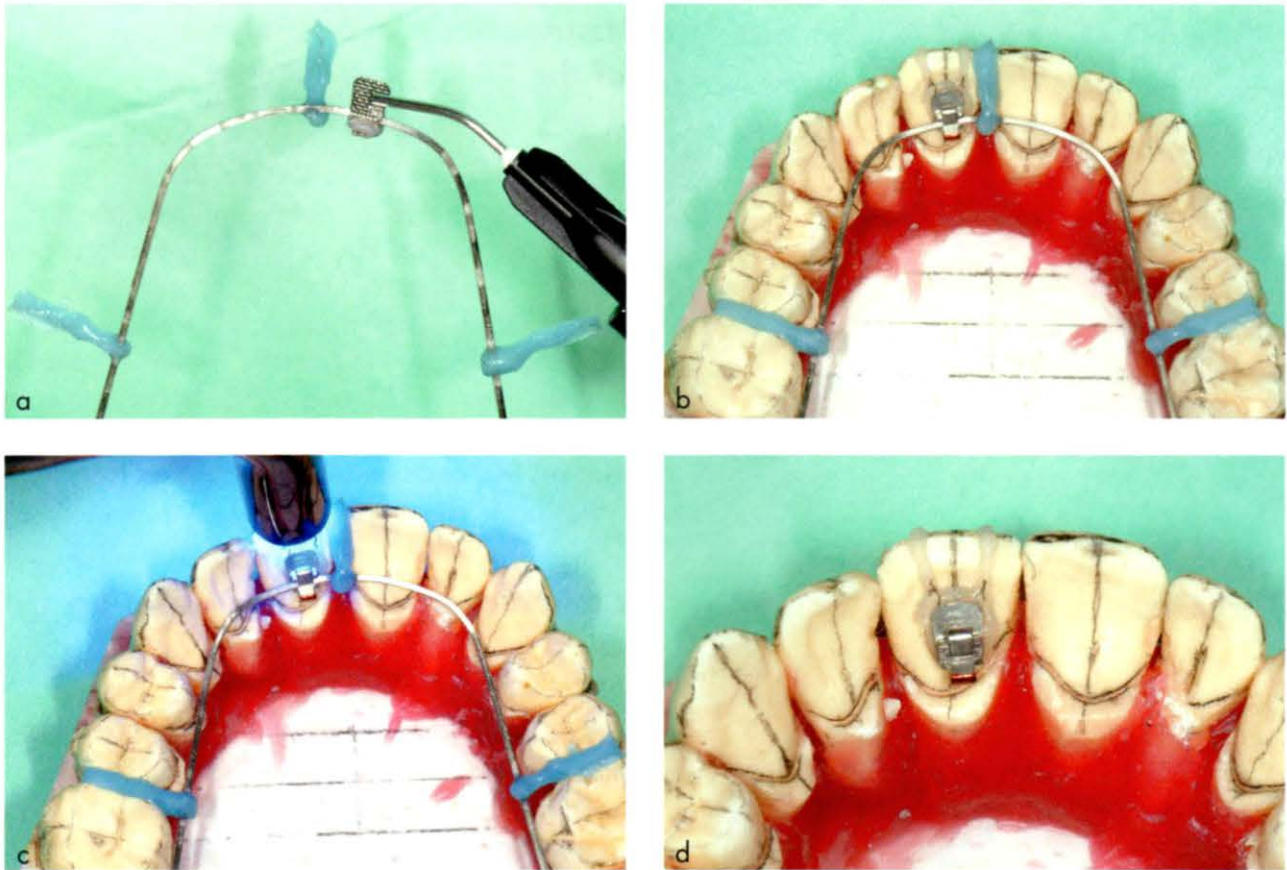
Fig. 10-27 The 3D archwire on the set-up model.

tooth or teeth by modifying the set-up even during the treatment.

Procedure

When a bracket is debonded for any reason, a new individual tray can be fabricated using the 3D reference archwire (Figs 10-25 and 10-26), which provides the exact original position of the bracket with all details of in-out, torque, and angulation.

The 3D archwire can be re-placed on the model in its original position for rebonding, whenever it is needed (Fig. 10-27). To rebond, place the bracket to be rebonded on the 3D archwire and tie with an elastic ligature. Check to see whether it is in the correct position. Fill the clearance between



Figs 10-28a-d Rebonding procedure using 3D archwire.

the bracket base and the lingual tooth surface with resin composite (Figs 10-28a to 10-28d). Follow the Komori procedure for a single tooth (see Chapter 17).

Advantages and Improvements

The system has some advantages compared with other conventional laboratory set-up systems:

- There is no need to transfer brackets from the set-up model to the original cast (malocclusion model), unlike with the CLASS system.
- Extractions, elastic separation, expansion and/or distalization can be carried out in the time period between taking of impressions and bonding.
- No individual transfer tray is required to bond the bracket to the tooth using the Komori system.
- The bonding has no relation with tooth alignment, so the fit of the bracket against the tooth is not affected by tooth movement.
- Limited composite overflow make maintenance of hygiene easier and reduces chair-side time, and the appliance is more comfortable for the patient.
- In cases of severe crowding, sequential bonding is easier to manage than with common lingual indirect bonding procedures.
- Rebonding is very quick and accurate with the set-up model and 3D archwire, and can be done directly at the chair-side in a few minutes.

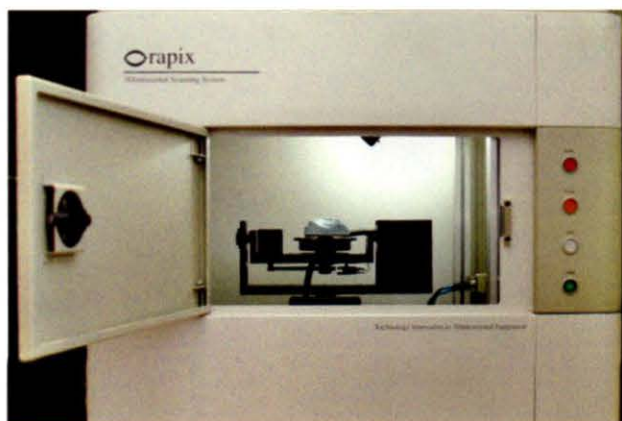


Fig. 10-29 The Orapix scanner.

The Orapix System

Today, laboratory procedures for bracket positioning and indirect bonding are taking advantage of the introduction of 3D digital methods. The Orapix system, developed by the South Korean company Orapix, utilizes this advanced technology to digitize dental study models, making them virtually viewable to create a virtual set-up from which CAD/CAM transfer trays can be designed and generated for indirect bonding of lingual brackets. The Orapix system permits positioning brackets in specific positions in order to use a straight wire technique and consequently to eliminate the disadvantages of archwire with multiple bends.

The Orapix system includes a scanner and two software programs: 3Dxer and 3Txer.

Digitization of Models

Digitization is performed using the proprietary "Slit system" scanner (Fig. 10-29) developed by Orapix. Digitization takes 8 minutes per pair of models. The different positions of the models during digitization provide a surface composed of triangles with extremities 200 micrometers apart. The data obtained must be edited to visualize the 3D images.

Visualization and Analysis of the 3D Images

The images of the study models are visualized by importing the file to the Orapix 3Dxer software, which can not only provide measurements of distances and angles, but can also, by making transverse and longitudinal cuts, allow appreciation of the occlusal relationship that had previously been possible only on – irreversibly – trimmed plaster models (Figs 10-30 and 10-31). The software can carry out calculations, including several indexes that can be used as diagnostic tools (Fig. 10-32).

Construction of the Virtual Set-up

Segmentation

The next step is segmenting the 3D dental arch into individual dental elements. In this procedure, which is obviously more delicate to carry out in crowded areas, each element receives a number signifying its placement in the arch (Fig. 10-33).

Normalization

The "tooth element" has to be perceived as a geometric unit. For each element, reference axes and strategic points need to be determined so that the teeth can be recognized and entered mathematically into the software in a process called "normalization", which is carried out by the second software, the 3Txer (Figs 10-34a to 10-34c).

Selection of Values for the Orientation of the Teeth

This is the first step in the creation of the virtual 3D set-up. The orientation prescription, which includes inclination, angulation, and height, determines the position of each tooth in the virtual set-up. A variety of prescriptions can be prepared according to different treatment plans, and saved in the program. The one finally selected is imported. Its values can be modified separately for each tooth.

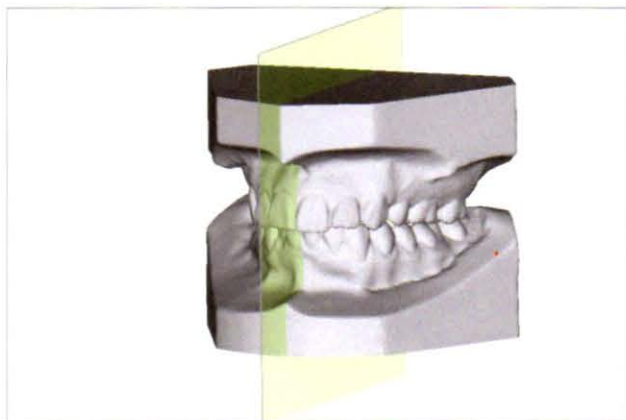


Fig. 10-30 Viewing the scanned models.

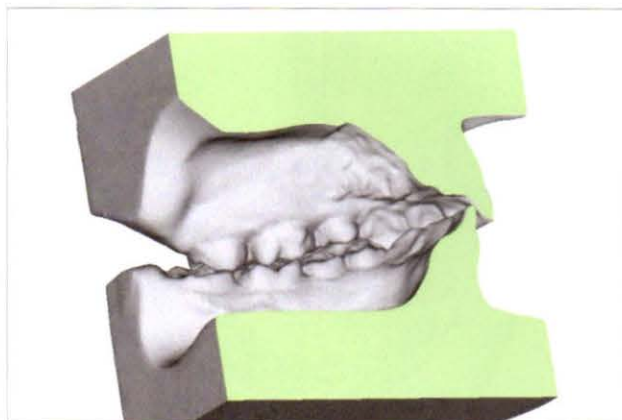


Fig. 10-31 Virtual cutting of the models.

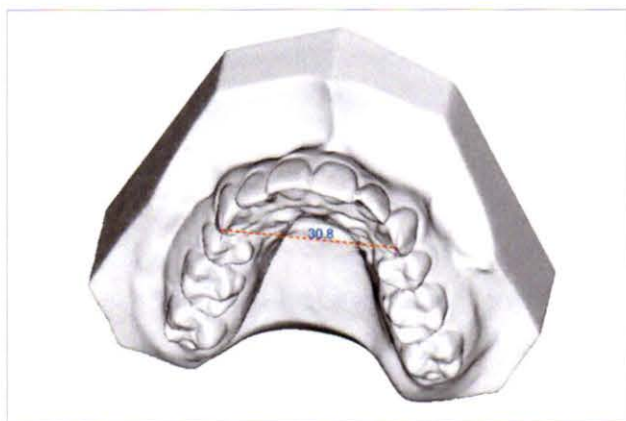


Fig. 10-32 Measurements made by the scanner.

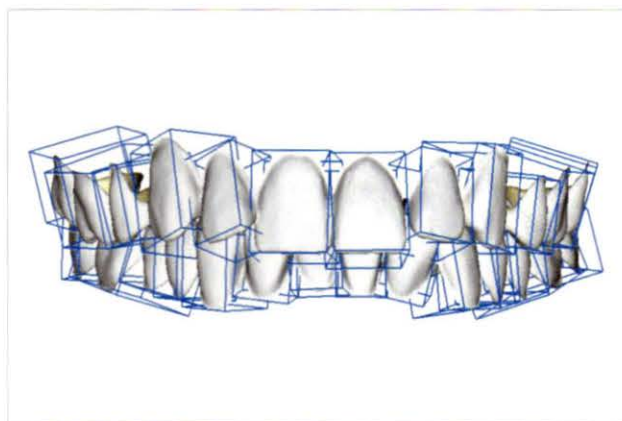
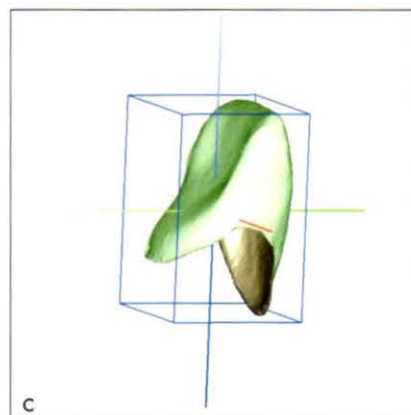
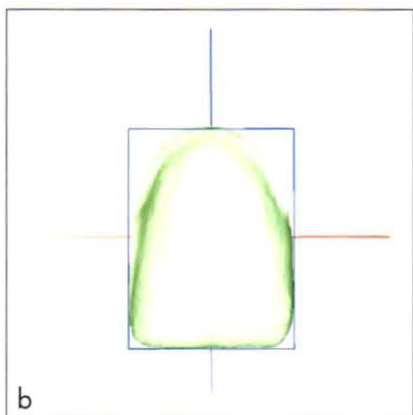
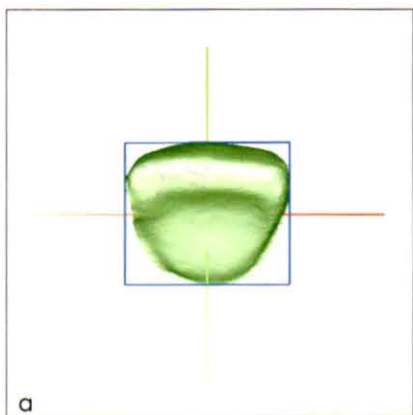
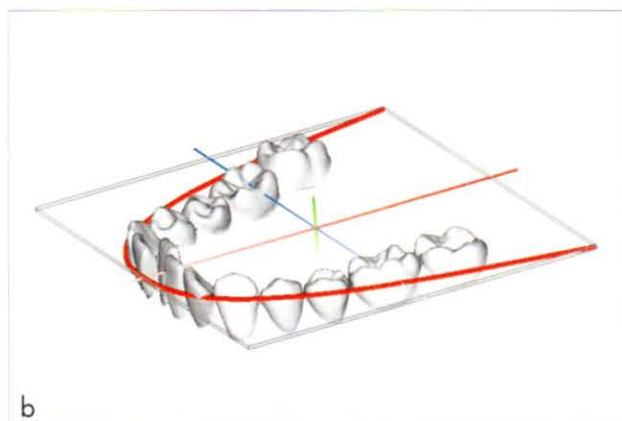
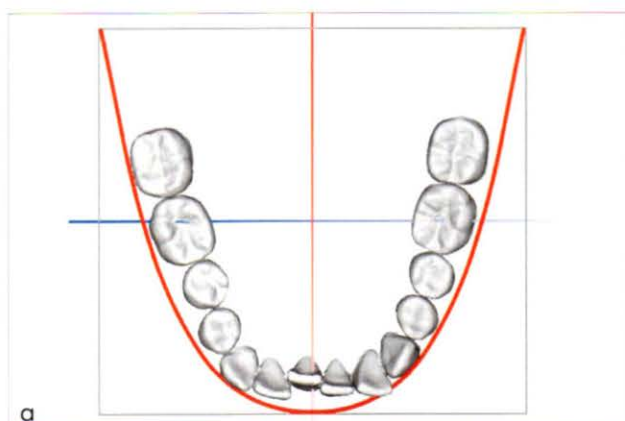


Fig. 10-33 Segmentation of the 3D dental arch.



Figs 10-34a-c Normalization: establishing the reference axes.



Figs 10-35a,b Selection of the labial curve.



Fig. 10-36 Contrasting colors show up the contact points.

Treatment Plan Selection

The 3Txxr software includes all the relevant information for the treatment plan selection: teeth to be extracted, teeth to be reduced, amount of reduction (0.1 mm to 2 mm), the amount of anterior tooth retraction, the amount of posterior tooth movement, as well as other data.

Arch Form Selection

A labial curve, selected from among a list of standardized curves, is superimposed on the occlusal view of the mandibular arch (Fig. 10-35a). This standardized curve, which can be modified and individualized to conform to the requirements of the treatment plan, will serve as a framework for positioning teeth in the virtual set-up (Fig. 10-35b).

Final Construction of the Virtual Set-up

This is first done automatically. The teeth are placed in contact in accordance with the labial curve and orientated according to the selected prescription. In the next step, the teeth in the two arches are manually adjusted to fit the final desired treatment result. The teeth can be moved vertically, horizontally, and laterally.

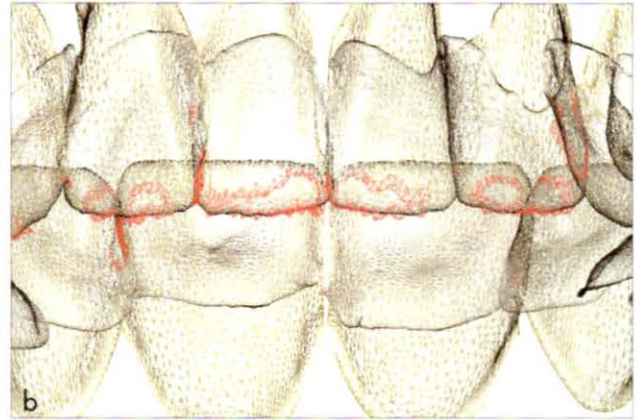
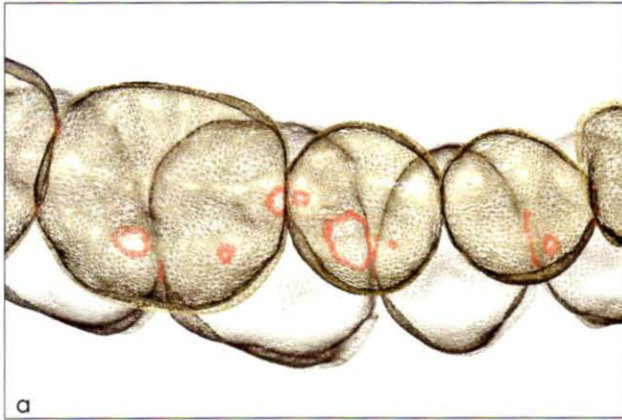
Search for the Ideal Occlusion

By moving the images in various directions of the two arches in occlusion, the occlusal contacts can be visualized. The colors used for the virtual teeth make it possible to clearly see the contact points (Fig. 10-36). In this way, the clinician can make occlusal adjustments to achieve as many occlusal contacts as possible. In addition, the "collision test" allows for even further precision by zooming the image, so that the contact points, which appear in red, can be further refined (Figs 10-37a and 10-37b, Fig. 10-38). The freedom with which the virtual set-up can be moved and manipulated in all planes of space enables control of the occlusion in every possible orientation (Figs 10-39a to 10-39d).

Virtual Bracket Positioning

Selection of the Virtual Brackets

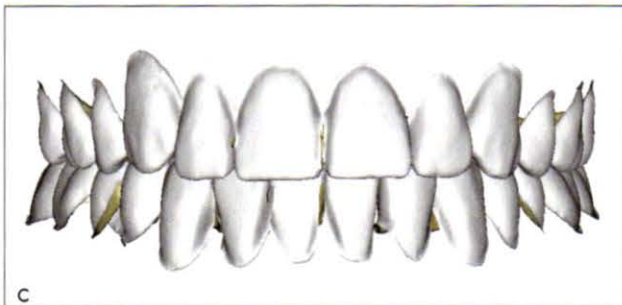
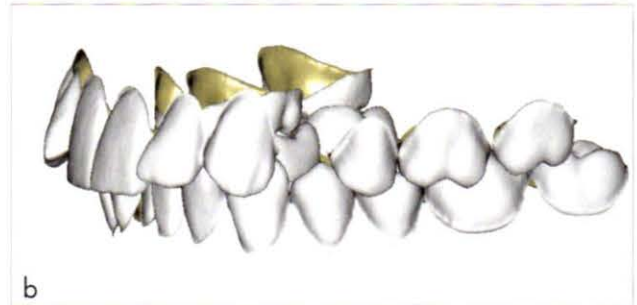
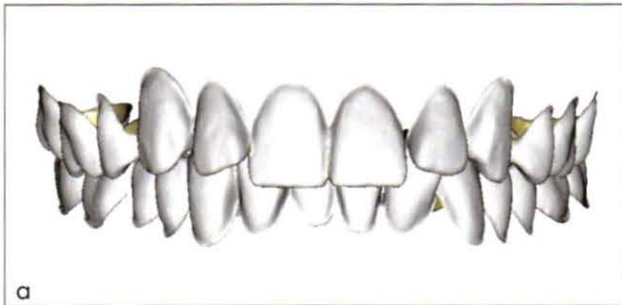
Once the occlusal contacts have been established, the lingual brackets can be selected. They all



Figs 10-37a,b The contact points appear in red in the “collision test”.



Fig. 10-38 A zoomed-in image of part of the set-up.



Figs 10-39a–d The virtual set-up is moved into different positions.

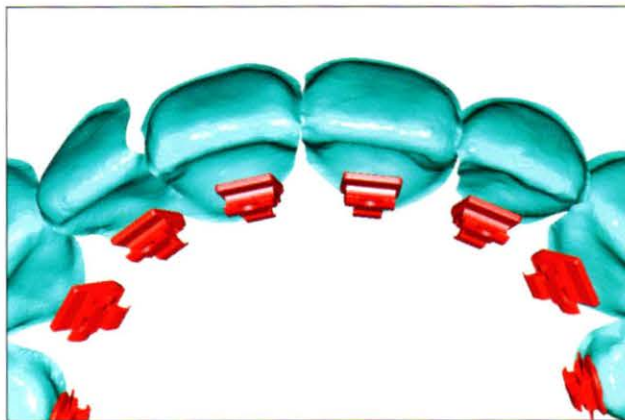


Fig. 10-40 Virtual brackets visualized in a plane parallel to the occlusal plane.

appear in the same virtual plane, which is parallel to the occlusal plane. The lingual brackets can be placed according to conventional lingual techniques (mushroom archwire shape) or the straight wire lingual techniques (without in/out bend).

Conventional Bracket Placement (Mushroom Archwire Shape)

To simplify the bending of archwires for clinical use, bracket positioning has to conform to a number of criteria, which correspond to those defined and used previously in the CLASS system (Newark 1986), the BEST system (Fillion 1989), and the Hiro system (Hiro 1996).

The brackets are placed in the same horizontal plane and centered on each tooth. The anterior bracket slots are positioned at the same minimal distance from the labial surface on a curve parallel to the labial curve selected for tooth placement in the virtual set-up. This minimal distance is determined by the contact of the bracket on the thickest tooth (Fig. 10-40). The positioning at a common minimal distance is carried out in the same way for the premolars and molars. Positioning of the virtual brackets requires the following steps:

- The brackets are moved in the vertical plane to find the ideal height. The posterior view allows appreciation of contacts between the mandibular teeth and the maxillary brackets (Fig. 10-41).



Fig. 10-41 By viewing from the posterior aspect, contact between the mandibular teeth and the maxillary brackets can be appreciated.

- The six anterior brackets are moved forward together toward the virtual lingual surfaces of the canines and incisors until the first visible contact occurs – seen as a contrast of colors (Fig. 10-42).
- The brackets are then centered in the middle of each virtual tooth. In this new position, the contact points of the brackets and the virtual teeth are adjusted and the brackets are moved backward until all contacts disappear (Figs 10-43 and 10-44).
- The same procedure is followed for the premolars and the molars.

Construction and Printing of the Virtual Lingual Archwire

Once bracket positioning has been completed, the software can create the virtual archwire, which will pass through the center of the bracket slots. Blue dots appear on the archwire between the canine and premolar brackets and between the premolars and the molars. These dots indicate where the bends have to be placed on the mushroom-shaped archwire and can be moved mesially or distally as required (Figs 10-45a to 10-45c).

By using the “data report” function, a printout is obtained of the actual size of the mushroom-shaped lingual archwire, which has been designed in 3D. Using this as a template, the clinician can bend the required archwires rapidly and precisely (Fig. 10-46).

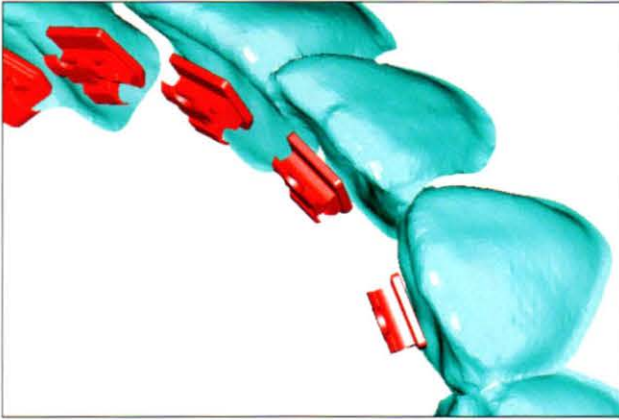


Fig. 10-42 The anterior brackets are moved forward until the canine bracket contacts the lingual surface of the virtual canine.



Fig. 10-43 Centering of each bracket.



Fig. 10-44 The anterior brackets appearing through the virtual surfaces.

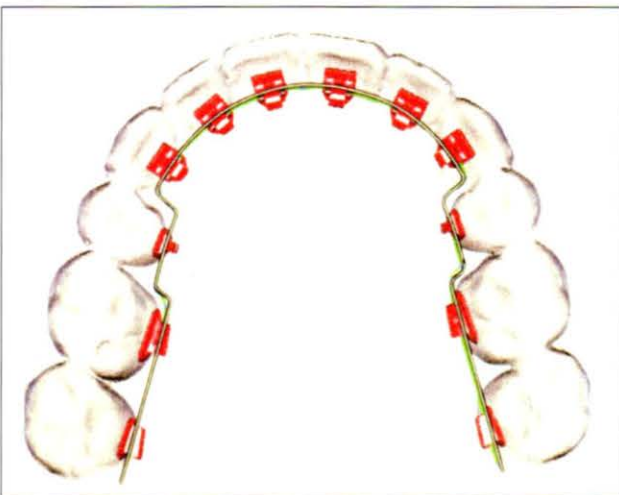
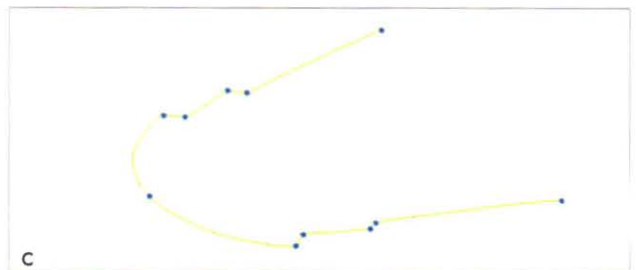
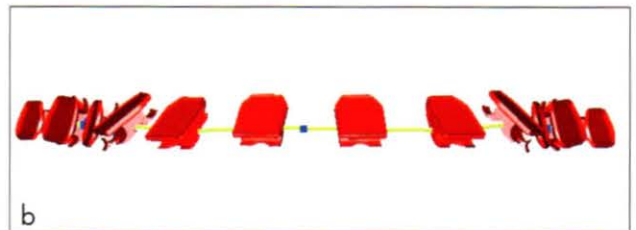


Fig. 10-46 Archwire bending, using the printed lingual archwire template.



Figs 10-45a-c Construction of the virtual ideal archwire.

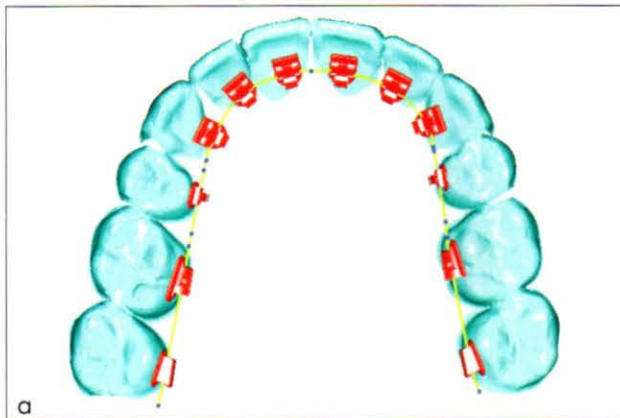


Fig. 10-47a,b Brackets placed in specific positions to eliminate the need for bends in the archwire.



Fig. 10-48 Case A: initial occlusion.

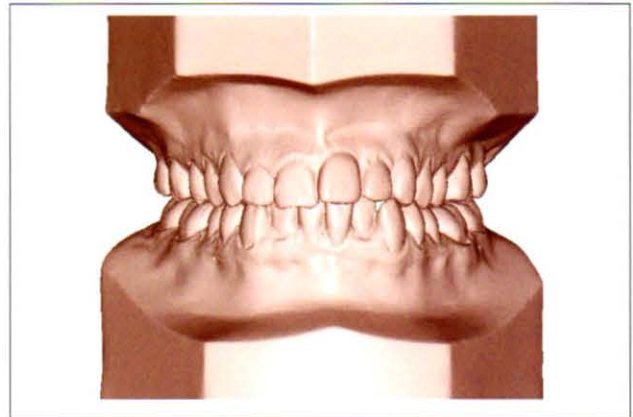


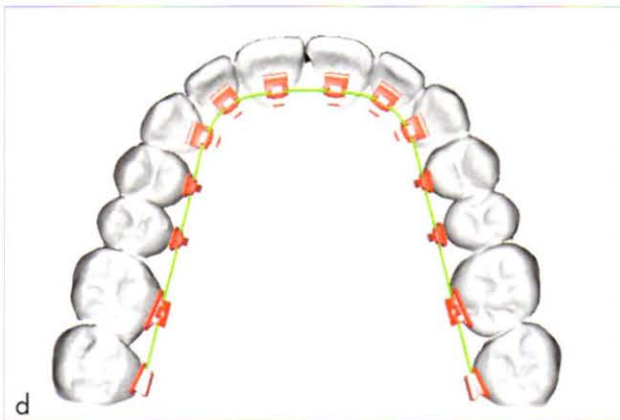
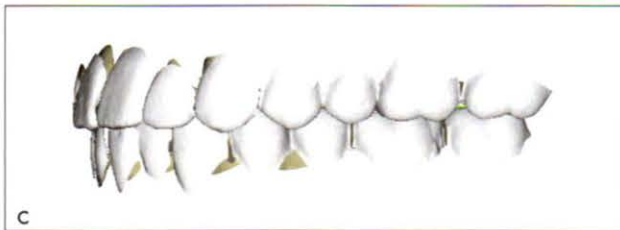
Fig. 10-49 Case A: virtual model of the initial occlusion.

Bracket Placement for Lingual Straight Wire Technique

The Orapix system makes it possible to place the brackets in specific positions so as to eliminate the need for adding any bends in the archwires. In this way, the lingual technique becomes a lingual straight wire technique (Figs 10-47a and 10-47b).

Figures 10-48 to 10-58 show two cases at the first stage of treatment to illustrate the simplified lingual technique.

When mushroom-shaped archwires are used, the incisor brackets are relatively far from the lingual surfaces because this position depends on the thickness of the canines. In the lingual straight wire technique, the position of the incisor brackets no longer depends on the thickness of canines. The incisor brackets are placed so as to make the best possible contact with the lingual surfaces. To eliminate the bends between the canines and premolars, the canine brackets must be placed rotated (distal off-set); likewise to eliminate the bends between the



Figs 10-50a-d Case A: virtual set-up.



Fig. 10-51 Case A: initial maxillary arch.

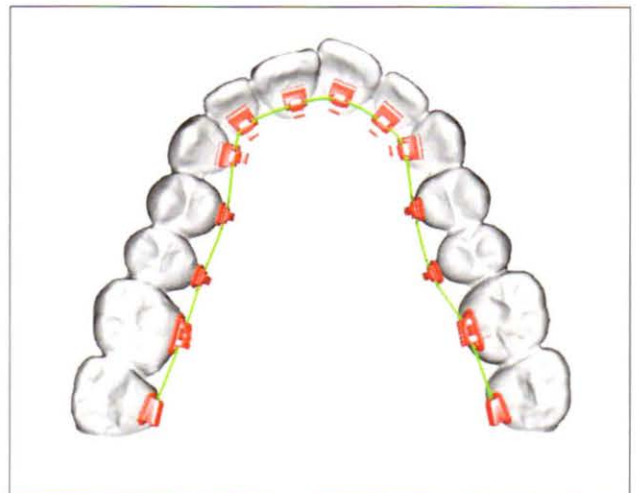
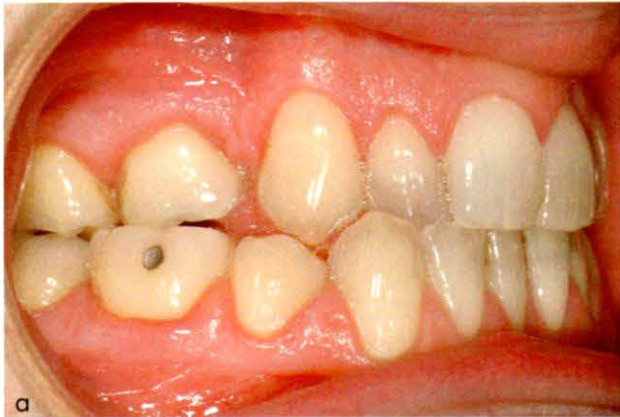


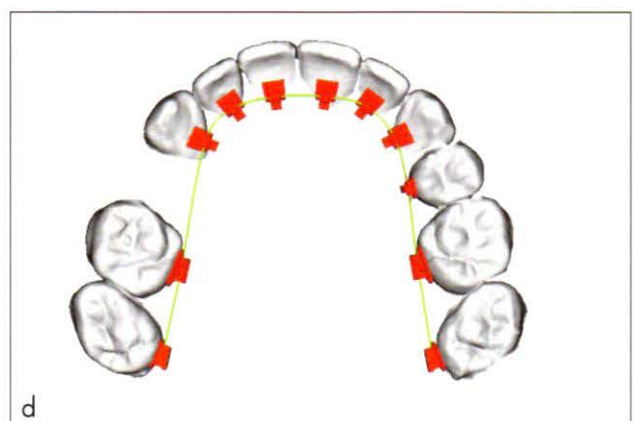
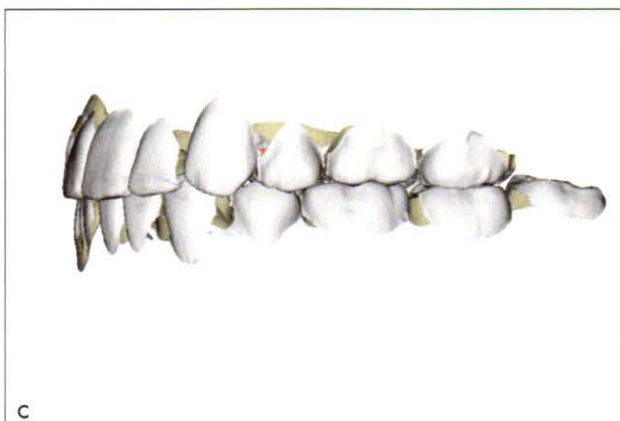
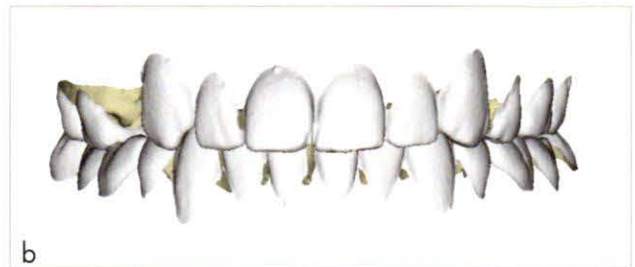
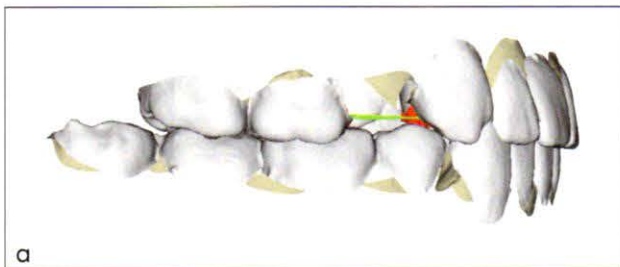
Fig. 10-52 Case A: virtual initial maxillary arch with virtual brackets in place.



Fig. 10-53 Case A: maxillary archwire placement.



Figs 10-54a-c Case B: initial occlusion.



Figs 10-55a-d Case B: virtual set-up.



Fig. 10-56 Case B: initial maxillary arch.

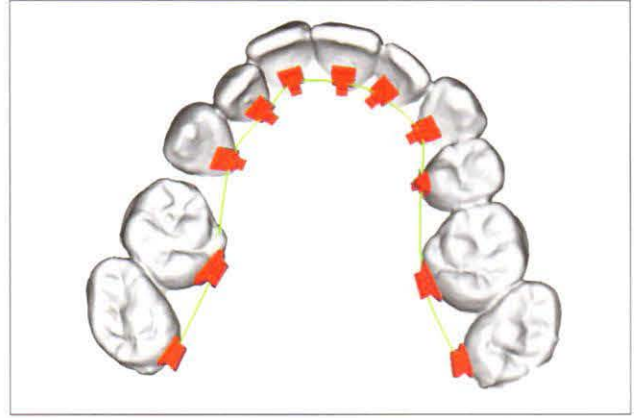


Fig. 10-57 Case B: virtual initial maxillary arch with virtual brackets in place.



Fig. 10-58 Case B: maxillary archwire placement.



Fig. 10-59 Virtual brackets visualized in a plane parallel to the occlusal plane.

premolars and molars, the second premolar brackets sometimes must be positioned slightly rotated (according to the thickness of the first molars).

For the lingual straight wire technique, the brackets are positioned as follows:

- The brackets are moved in the vertical plane to find the ideal height of the slots (Fig. 10-59). This height is slightly more than the height selected for the mushroom archwire technique (0.5 mm to 1mm) to compensate for the difference of thickness between the canine and the premolar. The new STb brackets with gingival off-set are perfectly adapted to this height modification.
- The incisor brackets are moved forward toward the virtual lingual surfaces until contact occurs (Fig. 10-60).
- The first molar brackets are moved toward the virtual lingual surfaces until contact occurs (Fig. 10-61).
- The archwire is developed by the software and displayed on the screen, passing through the center of the slot of each bracket (Figs 10-62a and 10-62b).
- The premolar and second molar brackets are moved forward so that the lateral part of the wire becomes straight (the first premolar bracket is placed as close as possible to the lingual surface).
- Each incisor and molar bracket is centered in the middle of the tooth (Fig. 10-63).
- The canine and second premolar brackets are positioned slightly away from the lingual surfaces with a distal offset (Figs 10-64a and 10-64b).



Fig. 10-60 The incisor brackets moved toward the virtual lingual surfaces.

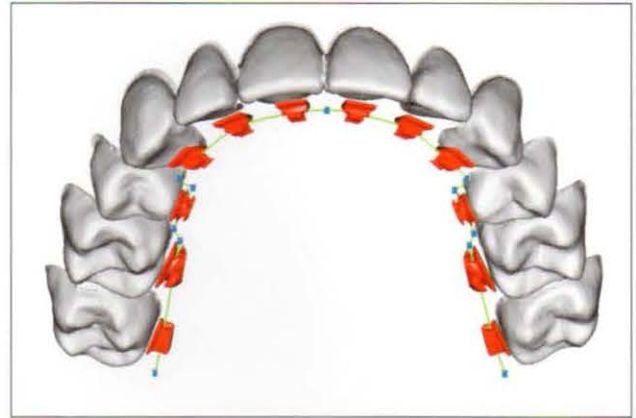
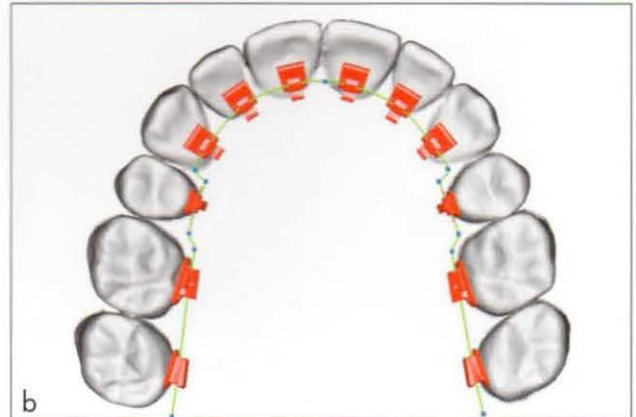
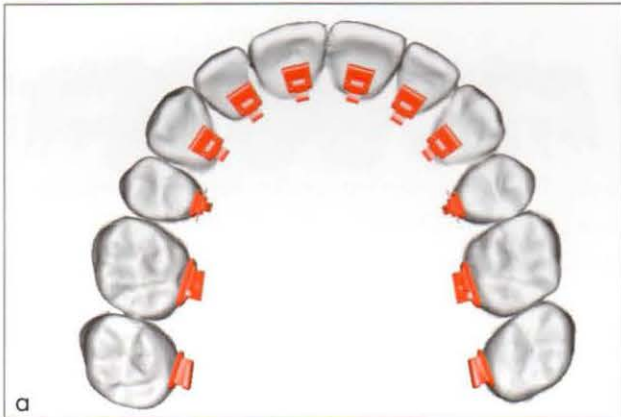


Fig. 10-61 The first molar brackets moved toward the virtual lingual surfaces.



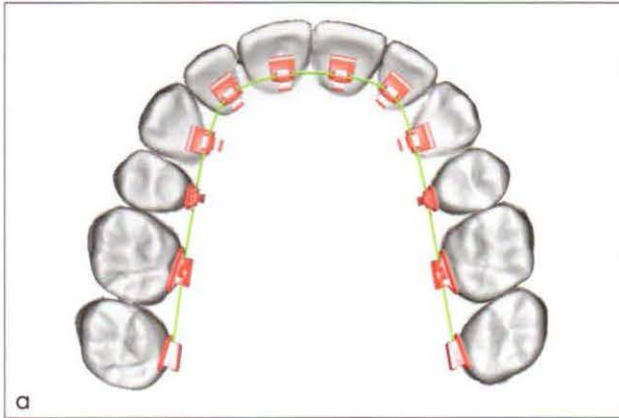
Figs 10-62a,b The wire automatically passes through the center of the slot of each bracket.



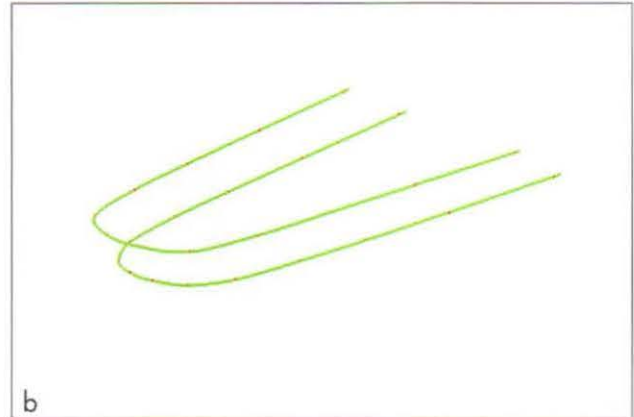
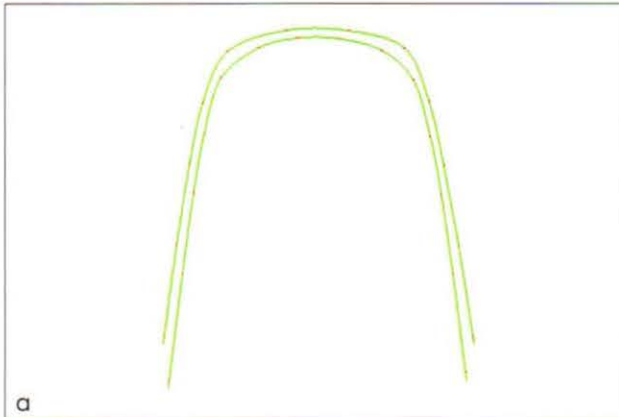
Fig. 10-63 Centered position of the incisor and molar brackets.

Construction and Printing of the Virtual Lingual Straight Wire

The virtual lingual straight wire is designed according to the position of the brackets. The anterior part of the maxillary straight wire is flatter and usually there is no concordance between the maxillary and mandibular archwires. By using the "data report" function, a printout is obtained of the actual size of the lingual straight wire (Figs 10-65a and 10-65b).



Figs 10-64a,b Canine and second premolar brackets have a distal offset.

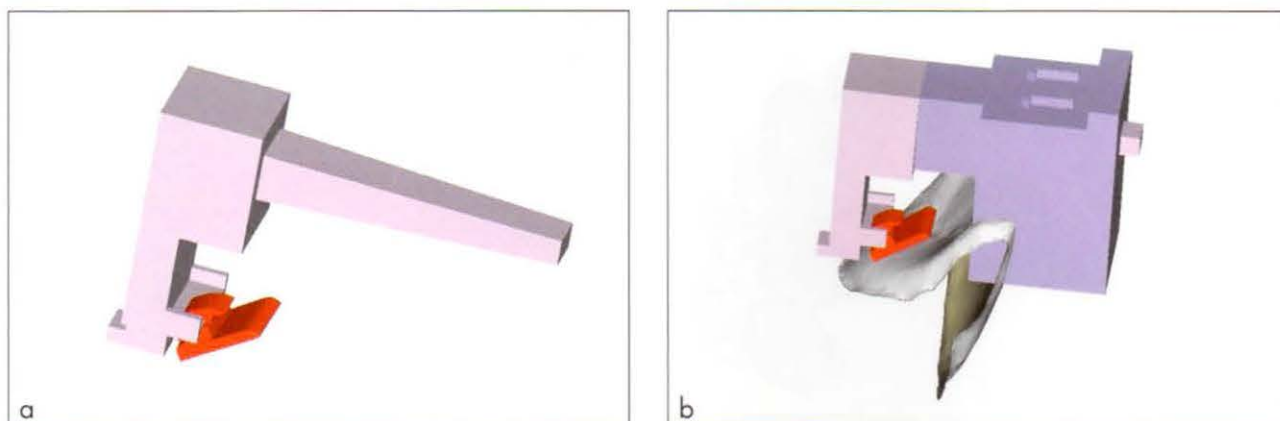


Figs 10-65a,b Printouts of the maxillary and mandibular lingual straight wire.

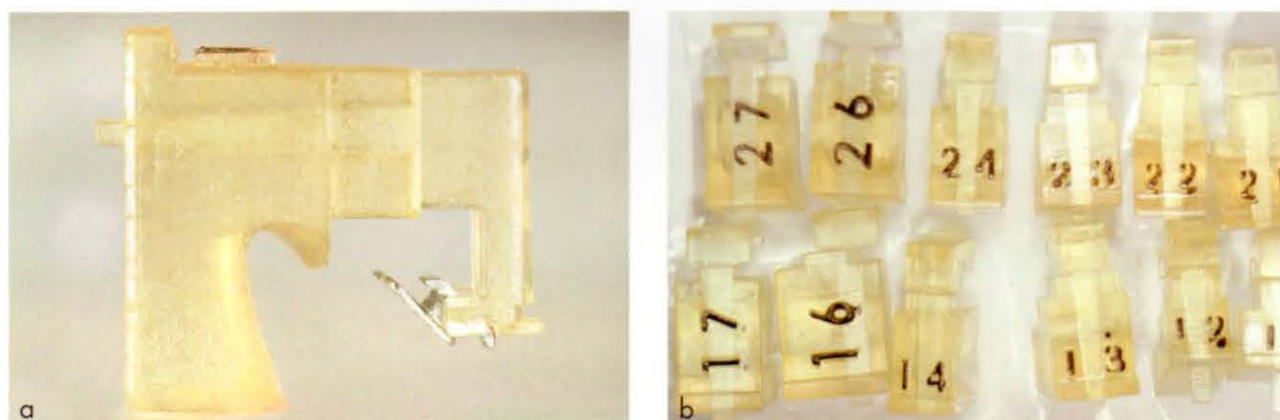
Construction of Individual Transfer Jigs

Transfer jigs or individual trays ensure the correct relationship between bracket and tooth. Using the jigs, operators can establish the position of each bracket in space, with respect to the tooth on which it will be bonded. The jigs are constructed, first virtually, in two parts. The first part fits perfectly into the slot of the virtual bracket and the other part covers the buccal and occlusal surfaces of the teeth and, in the case of the anterior teeth, 1 to 2 mm of the lingual surface (Figs 10-66a and 10-66b). The

"bracket part" of the jig can slide along the "tooth part" until establishment of contact limits movement of the bracket toward the tooth. A Rapid Prototype Machine then constructs, in real time, the "tooth" part of the jigs, using layers of resin. The standard "bracket" part is made of metal or resin (Figs 10-67a and 10-67b).



Figs 10-66a,b Construction of the virtual transfer jigs.



Figs 10-67a,b Jigs built by the Rapid Prototype Machine.

Construction of the Bracket Resin Pads and the Silicone Transfer Tray

Using the jigs, the real brackets are bonded with a resin composite to the models. The composite fills the gap between the metallic base of the bracket and the lingual surface of the tooth. The individualized resin pad is built up at this time (Figs 10-68a and 10-68b). After polymerization, the "bracket part" of the jigs is pulled away from the "tooth part". The bonded brackets are covered with a silicone material (Memosil, Heraeus Kulzer, Germany) or using the Komori bonding procedure. The tray, which is similar to the one used for the BEST system, is then

ready to be used in the patient (Fig. 10-69). The real brackets are thus placed in the same positions on the teeth as were the virtual brackets.

Advantages of the Orapix System

A Communication Tool

Using the Orapix system, the orthodontist can see virtual images of a patient's study models as well as those of a set-up depicting the final result of treatment on a computer screen. These pictures can also be sent via the internet to any desired destination and saved on CD-ROMs.

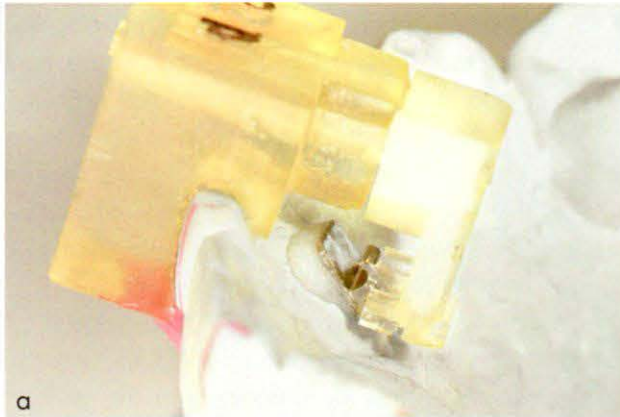


Fig. 10-68 (a) Bonding the bracket with the help of the jig. (b) All brackets are bonded, using the jigs, on the initial model.



Fig. 10-69 A reinforced silicone transfer tray is built to transfer the brackets to the patient's teeth.

With the Orapix system, patients can see what their teeth could look like after treatment and even the morphing process as the teeth move from present to future positions. They can see their teeth repositioned in individually selected positions that reflect the anatomic and functional requirements of the best occlusion possible.

Visualization and Selection of the Treatment Plan

Using the Orapix system, the orthodontist can visualize the final result they could obtain with a variety of potential treatment plans much more quickly than

they could do by making comparable multiple setups with plaster teeth. Thus the Orapix system has become an invaluable tool for orthodontists while making their therapeutic decisions. For example, the clinician can:

- visualize the anteroposterior discrepancy between the arches that would result from the removal of a mandibular incisor and how much tooth material they would need to strip from the maxillary anterior teeth to compensate for it
- evaluate the final occlusion that could be obtained after treatment of a severe retruded mandible with extraction of two mandibular premolars and surgical advancement of the mandible



Fig. 10-70 Overcorrection on the teeth.

- visualize and compare the respective occlusions that would be obtained with treatment accomplished with extraction of maxillary first premolars and treatment accomplished with extraction of maxillary second premolars
- compare the final position of the mandibular incisors that would result after treatment involving extractions and treatment involving stripping.

Many more examples can be cited of how the capability of visualizing what the final result would be can help the orthodontist to make decisions when they have to choose between a variety of possible treatment plans for the correction of a single malocclusion. Esthetic considerations are also fully taken into account in this method. Angulation, inclination, and the height of each tooth can be evaluated and, if necessary, adjusted so that the most pleasant smile for each patient can be constructed.

Precision Bracket Positioning

- The virtual brackets are positioned in a horizontal plane in such a manner that a flat archwire will produce in the clinic the same occlusion obtained in the virtual set-up. The brackets are not placed according to a standardized prescription but according to the *position each tooth occupies* in the virtual set-up. On initiation of treatment, the teeth will gradually move into this ideal position.

- In order to obtain satisfactory alignment, the operator must ensure that the brackets are centered and that their slots are parallel with the incisal edge or occlusal surface (except canine and premolar brackets, when using the lingual straight wire technique). Centering of brackets has, until now, been determined at the time of bonding the brackets to the plaster model either with an ideal archwire, in the Hiro system, or with a horizontal bracket holder (CLASS system) that also measures the distance from the bracket slot to the labial surface, as in the BEST system. As a result of the anatomic irregularities encountered on the lingual surfaces of teeth, centering and parallelism were often difficult to achieve with precision at the time of bonding on the models. With the enlarged virtual images of the teeth and the brackets that Orapix provides, this operation can be accomplished with precision, independent of the bonding sequence.
- Manufactured using CAD/CAM technology, the precise transfer jigs help reproduce in the clinic the bracket positions determined on the virtual set-up.

Overcorrection

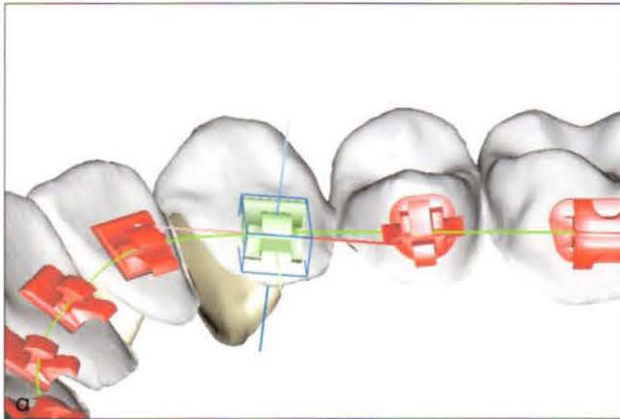
As in any other bracket positioning technique, it is easy to incorporate overcorrections. There are two ways of achieving this.

Overcorrection on the teeth

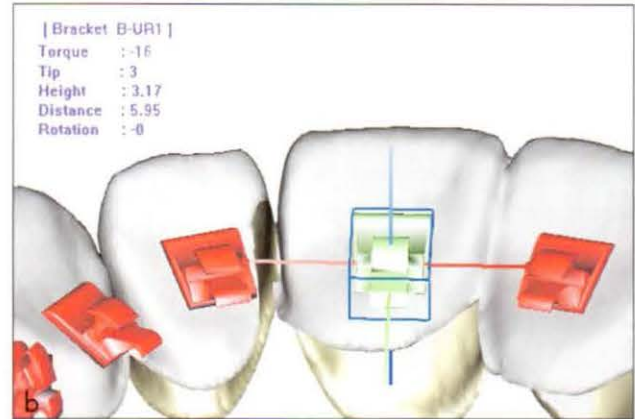
Two set-ups are prepared: the first, the esthetic set-up, shows the final tooth positions in the final ideal occlusion; the second set-up is made from the first but incorporates overcorrections (Fig. 10-70).

Overcorrection on the brackets

By using the esthetic set-up, after having placed the brackets in a horizontal plane as described above, the position of some of the brackets is modified according to the amount of overcorrection needed for angulation, inclination, and the bonding height (Figs 10-71a and 10-71b).



Figs 10-71a,b Overcorrection on the brackets



Decreasing the Risk of Error

In the Orapix system, the laboratory procedure carried out by the technician is limited to bonding the brackets and constructing the resin pads with the transfer jigs. This task does not require the technician to make any decisions about bracket positioning, since the positions have already been determined by means of the virtual set-up. This greatly reduces the risk of mistakes in the laboratory procedure.

Control of the Set-up and Bracket Placement

The Orapix system enables every clinician to become his or her own laboratory technician. Set-up and bracket positioning are done at an Orapix center. The virtual set-up is sent back electronically (via the internet) for checking and possible modification by the clinician. They can then verify or modify by double clicking on a selected tooth or bracket to gradually move it in all three planes of space. They can incorporate overcorrections even after the completion of the set-up and bracket placement. These can compensate for undesirable side effects that may occur during treatment, eg, excessive lingual tipping of maxillary incisors when they are retracted en masse with an undersized archwire or the excessive labial tipping of mandibular incisors that sometimes accompanies Class II mechanics. As described above, an ideal set-up is created to serve

as a communication tool and the overcorrections are incorporated directly on the brackets.

Bracket Rebonding

For rebonding a bracket, the transfer jig is used to rebond the bracket on the initial model. The bracket will have the same original position, the same as on the virtual set-up. Then the Komori procedure is used as described above. This procedure with the transfer jig is easily realized in the office. The jigs are not used for rebonding directly in the patient's mouth.

Additional Advantages of Lingual Straight Wire Bracket Placement

Use of Individualized Preformed Archwires

The clinician receives all the archwires required for treatment from Orapix. The wires are flat and do not have any bends. Identical in form, they are designed to gradually achieve the treatment goals determined by the set-up. The form determined by the set-up is used throughout treatment with the exception of the retraction phase in extraction cases. The individualized template allows easy and immediate replacement of a wire in the event of breakage. Thanks to the preformed archwires, chair-side time is reduced with the Orapix and the straight wire lingual technique.

Torque Control

Lingual straight wire bracket placement differs from conventional mushroom archwire technique bracket placement. A study of 30 cases compared the bracket positioning in the mushroom archwire technique with the bracket positioning in the lingual straight wire technique. The results show that in the straight wire technique (mean values):

- maxillary incisor brackets are closer to the lingual surfaces (1 to 1.5 mm)
- mandibular incisor brackets are closer to the lingual surfaces (0.7 mm)
- upper canine brackets are further away from the lingual surfaces (0.3 mm)
- second premolar brackets are further away from the lingual surfaces (0.3 to 0.6 mm)

As the incisor brackets are placed closer to the enamel (in contact for the central) and because the thickness of the STb brackets is only 1.5 mm, the bracket-tooth distance is greatly reduced, permitting better torque control. On the maxillary canines, the distal section of the bracket no longer makes contact with the enamel but the distance is only increased by only an average of 0.3 mm in the middle of the bracket.

It is important to emphasize that the incisors are the anterior teeth that induce the most difficulties for torque control.

A More Comfortable Appliance

The absence of bends in the archwire, particularly between the canine and premolar, makes contact between appliance and tongue much more pleasant than with a "mushroom" archwire. In addition, the incisor bracket positions are not dependent on the thickness of the canines, so that these brackets are placed closer to the enamel and project less into the oral cavity.

Conclusion

The Orapix system not only positions lingual brackets in precisely predetermined positions with almost total elimination of the risk of human error, but also ensures that their individualized placement will help the clinician achieve the ideal occlusion selected in the virtual set-up.

Thus the Orapix system provides orthodontists the option of the lingual straight wire technique that resolves many clinical problems of the lingual technique and greatly simplifies its practice. Orthodontists will find they can finish the cases they treat with lingual orthodontics with less need for time-consuming finishing and achievement of the desired occlusion.

11 EXTRACTION MECHANICS AND ANCHORAGE CONTROL

Principles of Extraction Mechanics

Criteria for Extraction

Patients who undergo lingual orthodontic treatment are predominantly adults. In adult orthodontic treatment, the limited possibility of arch expansion often requires extraction. The purposes of extraction in orthodontic treatment include correction of tooth size–arch size discrepancy, improvement in the anteroposterior jaw relationship, and improvement of soft tissue profile.

Correction of Discrepancy

The criteria for extraction in lingual orthodontic treatment are the same as for the labial technique. Whether to extract is determined based on crowding (arch length discrepancy), the possibility of expansion or interproximal stripping, etc. Posterior discrepancy is also considered, since whether the molars can be moved distally or not is also included in the criteria for extraction. Considering the rather unfavorable status of the periodontal tissue in many adults and the duration of treatment required, tooth movements over a short distance are desirable.

Improvement in the Anteroposterior Jaw Relationship

When an excessive anterior overjet is present with an Angle Class II relationship, such as maxillary protrusion (Fig. 11-1), or anterior crossbite is present in an Angle Class III relationship, extraction may

be considered for correction of anteroposterior discrepancy in the jaw relationship even when the crowding is not so severe.

Improvement of Soft Tissue Profile

When the maxillary and mandibular anterior teeth are tipping labially and there is imbalance between the hard and soft tissues because of bimaxillary protrusion, although the relationship is Angle Class II, whether to extract is determined with due consideration of improving the profile as well as the occlusion.

However, sometimes it is also the case that, although an excessive anterior overjet is present, the profile shows mandibular retrusion, not protrusion of the maxillary anterior teeth. Moving the anterior teeth back in this situation may open the naso-labial angle and result in a retruded chin profile, although the occlusion improves. In such a case, surgery may be used in combination with orthodontics, to improve the occlusion and profile by forward move-



Fig. 11-1 Maxillary protrusion.



Figs 11-2a-d The face as a whole looks quite old with poor esthetics.

ment of the mandible. On the contrary, it may be also the case that extraction is not determined solely based on the profile when facial esthetics is considered. Facial muscles and skin lose elasticity with age. As a result of extraction, the lips will draw back and facial muscles such as orbicularis oris will lose their tone, leaving excessive skin, and wrinkles and sagging may develop. The face as a whole will look aged with poor esthetics (Figs 11-2a to 11-2d).

For these reasons, sometimes patients may complain of the result even though orthodontic treatment has improved the occlusion or the profile. Therefore, prediction of post-treatment facial change is important.

Other Criteria for Extraction

When jaw deformity is present, such as mandibular protrusion due to overgrowth of mandible, or maxillary protrusion due to insufficient growth of mandible, improving occlusion and maxillofacial morphology may be difficult if only orthodontic treatment is used. Then, a combined surgical and orthodontic approach is indicated, and extraction is considered in preparation for surgery. For example, in a case of mandibular protrusion, if chin protrusion is prominent while the molar relationship is close to Angle Class I, only a small amount of backward movement of the mandible will be possible with surgery and the profile may not be improved successfully. In that case, extraction in the maxillary arch prior to surgery will

allow the maxillary anteriors to move backward to some extent. Then the amount of backward movement of the mandible will be increased by surgery, and at the same time the profile will be improved.

On the contrary, in a case of maxillary protrusion, if the chin is retruded and the molar relationship is close to Angle Class I, only a small amount of forward movement of the mandible will be possible with surgery and the profile may not be improved satisfactorily. In that case, extraction in the mandibular arch prior to surgery will allow the mandibular anteriors to move backward to some extent. The amount of forward movement of the mandible possible with surgery will be increased and at the same time the profile will be improved. It is also the case that, in adult orthodontic treatment, whether to extract or not is decided by social limitations or personal values of individual patients. Sometimes, the duration of treatment may have to be limited, or the patient's social activities may influence the treatment plan.

Recently, implants are increasingly used as a source of anchorage in orthodontic treatment. Orthodontic implants enable distalization or intrusion of molars, which has been difficult to achieve with conventional mechanics. Thus, implants allow treatment of crowding without extraction (with extraction of the third molars only), which would otherwise be treated by extraction. Non-surgical treatment is also possible with orthodontic implants for open bite or mandibular protrusion which otherwise would require surgery. Indeed the introduction of orthodontic implants has greatly changed conventional orthodontic treatment planning.

Diagnosis and Selection of Teeth for Extraction

During selection of teeth to be extracted, the status of individual teeth should be taken into consideration as is done in conventional orthodontic treatment. Factors to consider include: periodontal disease; gingival recession; status of any pulp treatments; status of the roots; shape of the tooth crowns; shape of the occlusal plane; status of restored crowns if any; and location of missing teeth.

However, the teeth selected to be extracted in lingual orthodontic treatment often differ from those that would have been selected for labial treatment for a given malocclusion because of the peculiarity of lingual biomechanics. Teeth to be extracted in lingual orthodontic treatment are selected as follows based on the molar relationship.

Angle Class I Cases

In Class I cases, teeth to be extracted are selected usually based on general evaluation including the amount of crowding, tipping of anterior teeth and the profile. However, in some cases, a slight distal tipping of the mandibular molars may change the molar relationship from Class I to Class II. When such change happens, particularly in a high angle case, instead of the four first premolars, the maxillary first premolars and the mandibular second premolars may need to be extracted.

Angle Class II Cases

In Class II molar relationship cases, maximum anchorage is often necessary in the maxillary arch. Therefore, sometimes only the maxillary first premolars may need to be extracted. It is desirable to avoid extraction of the mandibular teeth. If there is only a small amount of crowding in the mandibular arch, it is recommended to labially tip, or strip, the mandibular anteriors.

In lingual orthodontics, anchorage value of the mandibular molars is particularly strong. Even when the mandibular second premolars are extracted, it is difficult to move the mandibular molars mesially. If two teeth are extracted despite a small amount of crowding in the mandibular arch, the extraction spaces will be used mostly for backward movement of the mandibular anteriors, and a considerable amount of overjet is likely to remain post treatment.

When extraction is necessary because of severe crowding in the mandibular arch or for correction of tipping of anterior teeth, extraction of an incisor should be the first choice, based on due consideration of the position of midline, gingival recession and restored teeth. It is sometimes the case that one

Box 11-1 Selection of extraction site (Class II case).

DIAGNOSIS : Class II case

- $\frac{4}{4} \mid \frac{4}{4}$ Ext
- $\frac{4}{4} \mid \frac{4}{4}$ Ext, lower slicing
- $\frac{4}{4} \mid \frac{4}{4}$ Ext, lower three incisor
- $\frac{4}{5} \mid \frac{4}{5}$ Ext
- $\frac{4}{4} \mid \frac{4}{4}$ Ext or Non Extraction

Box 11-2 Selection of extraction site (Class III case).

DIAGNOSIS : Class III case

- Orthognathic Surgery
- $\frac{4}{4} \mid \frac{4}{4}$ Ext
- $\frac{5}{5} \mid \frac{5}{5}$ Ext or lower three incisor
- $\frac{5}{4} \mid \frac{5}{4}$ or $\frac{4}{4} \mid \frac{4}{4}$ Ext
- $\frac{4}{4} \mid \frac{4}{4}$ Ext or Non Extraction

mandibular premolar is extracted, depending on the amount of crowding or deviation of the midline. A second choice is to extract two premolars. If the crowding is moderate and the molar relationship is Class II, extraction of the mandibular second premolars is effective in resolving crowding as well as establishing a Class II molar relationship.

In patients with severe crowding and a molar relationship close to Class I, usually the first premolars are selected for extraction. However, as mentioned above, since the anchorage value of mandibular molars is strong, the anchorage loss in the mandibular arch is small and the anterior teeth may move excessively backward, resulting in a Class II molar relationship post treatment. If the patient is not willing to accept compromised treatment, surgery must be considered (Box 11-1).

Angle Class III Cases

In lingual orthodontics, it is difficult to tip the mandibular anteriors labially in non-extraction treatment, although extraction of the premolars easily induces lingual tipping of these teeth. This is beneficial for improvement of anterior crossbite.

Previously, resin composite or light-curing glass ionomer cement was often applied to the mandibular molars for temporary bite raising. Because application of such materials to the mandibular molars tended to induce distal tipping, as a side

effect of the occlusal force, or lingual tipping of the mandibular anteriors, nowadays for bite raising the application is done on the occlusal surfaces of the maxillary molars. In labial orthodontics, the mandibular anteriors tip forward during leveling. On the contrary, in lingual orthodontics the mandibular molars tend to tip distally. In other words, if the length of arch is the same, the mandibular arch is leveled in the posterior segment more readily than in the anterior segment. This facilitates improvement of Class III molar relationships.

Patients who do not want to undergo surgical orthodontic treatment must accept a compromise involving either the midline or the canine relationship, while extraction of one of the first or second premolars or an anterior tooth will correct anterior crossbite. As described above, the teeth to be extracted are determined based on the difference in molar relationship. However, as implants are increasingly used as sources of anchorage in orthodontic treatment, the idea of anchorage is changing and, as a result, selection of teeth to be extracted is also changing.

The use of implants allows treatment with maximum anchorage. For example, when the anterior teeth are moved backward, it is not necessary to impose a counteractive forward force on the posterior teeth. In a patient in whom the first premolars had to be extracted in the maxillary arch when conventional orthodontic treatment is being used,

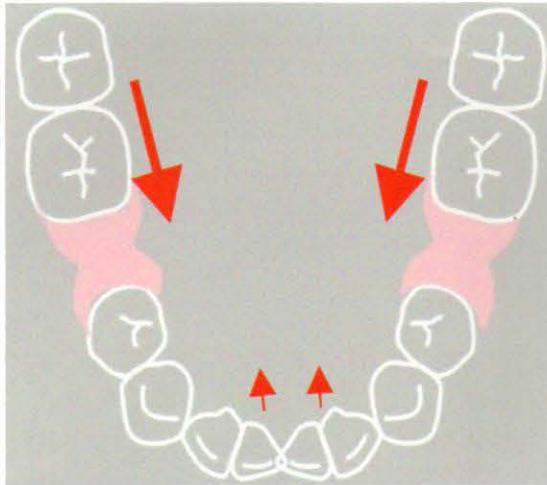


Fig. 11-3 Narrowed alveolar bone in the region of the extractions.

the use of implants allows treatment with extraction of the second premolars, and the first premolars can be moved backward together with the anterior teeth. In patients in whom mandibular second premolars had to be extracted conventionally, the use of implants allows the mandibular posterior teeth to move forward if the first premolars are extracted (Box 11-2).

Extraction and Periodontal Tissue

Throughout treatment, care should be taken with the health of periodontal tissue, especially when the mandibular second premolars are extracted.

Timing of Extraction of the Mandibular Second Premolars

In mandibular arches where the width of alveolar bone is narrow, extraction of the second premolars before leveling can make the mesial movement of the first molars, or distal movement of the first premolars, difficult because bone resorption in the extraction site will make the alveolar bone even narrower. This problem can also occur when the width of the alveolar bone is normal before extraction but if it is predicted that leveling will take a long time so the ensuing bone resorption will reduce alveolar

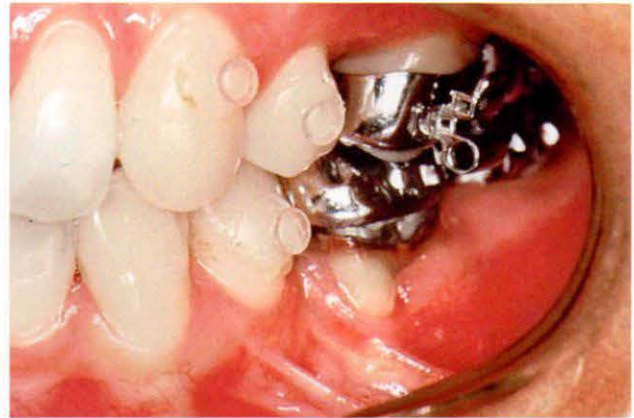


Fig. 11-4 A high buccal frenum.

width (Fig. 11-3). Therefore, it is recommended that extraction of the second premolars be delayed as late as possible.

Buccal Frenum Between the Second Premolar and the First Molar

When the buccal frenum between the second premolar and the first molar is attached at a high position (Fig. 11-4), the gingiva surrounding the first molar may recede after the second premolar has been extracted. Thus, care should be taken in selecting teeth to be extracted.

Unusual Extraction

Sometimes, failure to identify the appropriate teeth for extraction may result in extraction of teeth with negative factors, or a previously missing tooth's site has to be used as extraction space. If problems are present in the anterior teeth, including the lateral incisors, an anterior tooth has to be extracted. In such patients, the extraction may be irregular because extraction is uni-arch or unilateral, or the number of teeth is uneven.

When the midline is deviated and anterior retraction will be done by en-masse retraction, sometimes different extraction sites are selected on the right and left sides of the arch. For example, the second



Fig. 11-5 An unusual extraction pattern.

premolar may be extracted on the side toward which the midline is shifted, and the first premolar on the other side (Fig. 11-5).

When extraction is necessary in the maxillary arch, anatomical considerations such as the relationship between the maxillary sinus and the tooth roots will influence the selection of the teeth to be extracted for efficient tooth movement. If the base of the maxillary sinus is low, it is highly likely that the hard bone in the wall will inhibit tooth movement. Confirmation by computed tomography (CT) as well as by radiographs will be helpful during selection (Fig. 11-6).

Anchorage

It is said that lingual orthodontic treatment generally offers stronger anchorage than labial. Here we describe horizontal anchorage and vertical anchorage separately.

Horizontal Anchorage

Orthodontic force vectors imposed on the anterior teeth through the lingual orthodontic appliance are directed not exactly toward the rotational center of the teeth, but are deviated lingually so as to produce lingual crown torque in the anterior teeth. As a result,

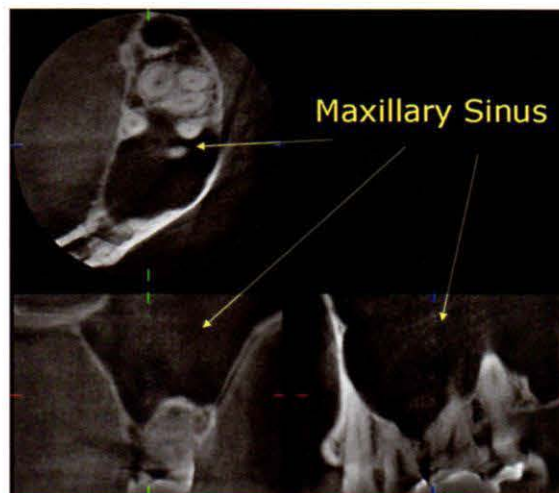
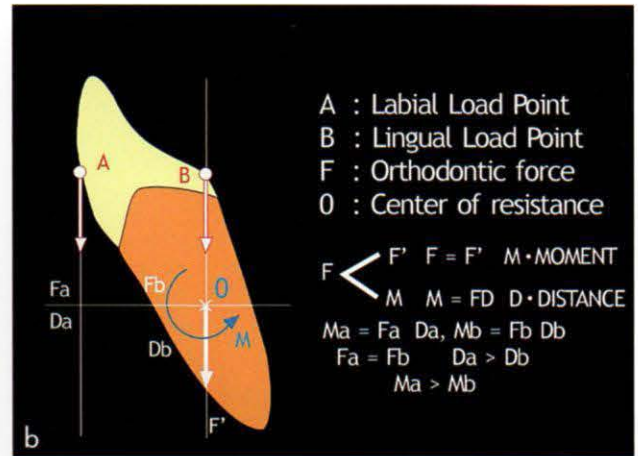
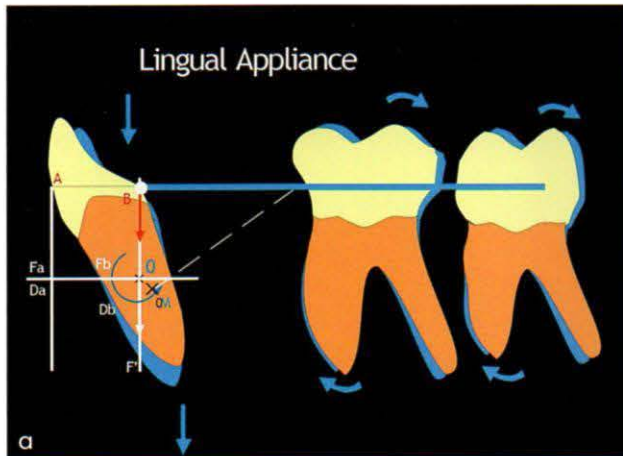


Fig. 11-6 Three dimensional CT view of the maxillary sinus area.

an upright force is imposed distally on the posterior teeth through the archwire and there is more resistance to anchorage loss in the posterior teeth (Figs 11-7a and 11-7b, Fig. 11-8). Molar anchorage is lost by mesial tipping of the molars. However, in lingual orthodontics, during en-masse retraction a distal tipping force is always imposed on the molars. Through the use of headgear, the increased amount of anchorage in the molar region is greater than that achieved with buccal orthodontic treatment.

Vertical Anchorage

As the brackets are placed on the lingual surfaces, it is easy to tip the molars lingually, and the lingual cusp position is controlled through constant application of buccal root torque (vertical anchorage) (Fig. 11-9). The lingual cusps in the maxillary arch are the functional cusps. Their vertical height is maintained without extrusion through application of an intrusive force. This is beneficial for controlling the lingual cusps of the maxillary second molars that are most susceptible to canine interferences. It also makes it possible to avoid unwanted effects such as molar extrusion, mandibular clockwise rotation caused by early contact, anterior open bite, or increased centric relation–centric occlusion (CR–CO) discrepancy due to deterioration of the Class II molar relationship.



Figs 11-7a,b Biomechanics in the mandibular arch (sagittal plane)

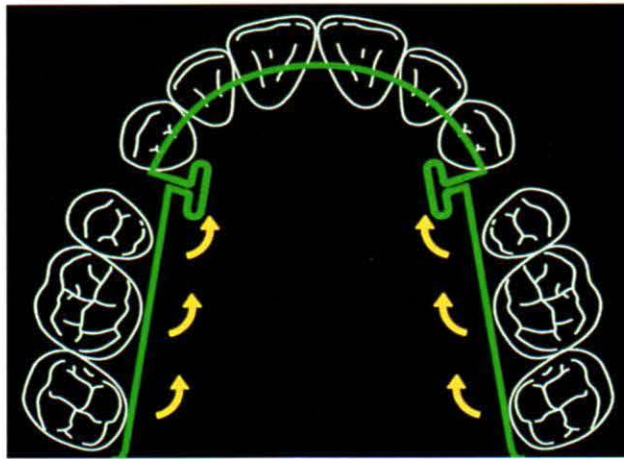


Fig. 11-8 Posterior teeth tend to rotate distally during anterior retraction.

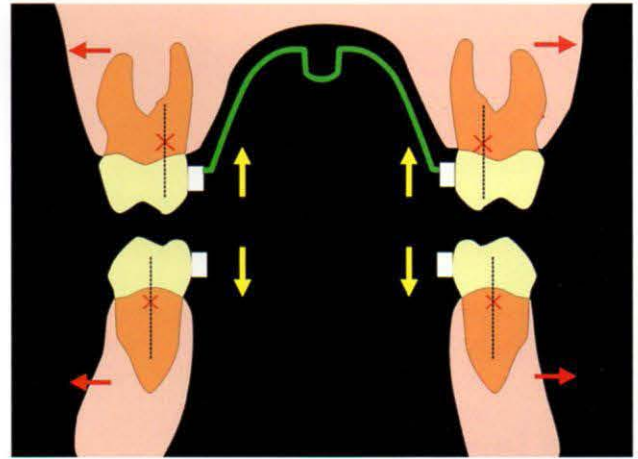


Fig. 11-9 Lingual tipping induced by lingually applied forces to the posterior teeth.

Distal tipping of the molars (vertical anchorage) and buccal root torque (horizontal anchorage) indicate the status of the "cortical bone anchorage". Elimination of tongue pressure through a lingual orthodontic appliance reinforces molar anchorage, and it is even stronger in the mandibular arch where bones are thin.

As mentioned earlier, currently implants are being used increasingly as a source of anchorage for orthodontic treatment, and our understanding of anchorage is changing. As far as there is sufficient bone for placement of implants, they can be used in almost any site. While implants are mainly used as

a source of anchorage to avoid undesirable counter-movements of teeth during extraction site closure, they are also effective for actively moving the molars distally or mesially. Also, they are useful for intruding the anterior teeth in deep bite cases or intruding the molars in open bite cases.

Implants are effective as maximum anchorage provided the clinician has a full understanding of the biomechanics of orthodontic treatment. Implants are not a panacea in lingual orthodontic treatment, and they should be used only with full knowledge of the biomechanics peculiar to lingual orthodontics.

Box 11-3 Treatment steps in extraction cases.**TREATMENT STEP**

1. Initial leveling
 - Partial cuspid retraction
 - 6 anterior leveling
2. Establishment of torque
3. En Masse retraction
4. Detailing

Treatment Mechanics in Extraction Cases

Treatment steps after extraction are roughly divided into four steps: (1) initial leveling; (2) establishment of torque; (3) en-masse retraction; and (4) detailing. This section describes the archwire sequence in each step (see also Box 11-3) and precautions to be taken with respect to treatment.

Initial Leveling

In lingual orthodontic treatment, initial leveling is done in two stages depending on the amount of crowding of the anterior teeth, namely, partial canine retraction and anterior leveling. Partial canine retraction is done to allow alignment of the four anterior teeth and anterior leveling of the six anterior teeth. Usually, full canine retraction is not done at this stage for the esthetic reason that this would create spaces between the anterior teeth, particularly between the lateral incisor and the canine, and also with due respect to the mechanics.

Methods of Partial Canine Retraction

Lingual arch Since a lingual arch allows retraction of canines and premolars as well as correc-

tion of crossbite with maximum anchorage without impairing lateral function, it is very effective when brackets cannot be properly placed due to severe anterior crowding. A lingual cleat attached to the lingual surface of the canine is connected to a spring soldered on a lingual arch with a power chain, and canine retraction is achieved with light continuous force. When there is anterior crossbite, it may be corrected with a finger spring simultaneously with canine retraction (Figs 11-10a and 11-10b). When the patient bites the appliance because of the presence of a deep bite, or when a crossbite is to be corrected, resin composite or glass ionomer cement is applied to the maxillary second molars to raise the bite (Fig. 11-11). The amount of the material to be applied is smaller and the time for it is required is shorter than when brackets are placed from the beginning. Thus it imposes fewer burdens on patients and lateral function is hardly impaired. After crowding is corrected and teeth are ready for proper bracket placement, bonding is done using individual caps made with the Hiro system. Next, anterior leveling is initiated (Figs 11-12a and 11-12b).

Full archwire with loops (0.012, 0.014, 0.016 nickel titanium [NiTi] wire, 0.016 titanium molybdenum alloy [TMA] wire)

When anterior crowding is mild and only a small amount of canine retraction is required, loops are incorporated in the leveling wire and canine retraction is done with sliding mechanics using a power chain (Figs 11-13a to 11-13c). Retraction from the loop but not from the second premolar bracket prevents the second premolar from tipping forward, thus avoiding impairment of lateral occlusal function. When crowding prevents bracket placement, NiTi open push coil springs are used between the anteriors to actively make space (Figs 11-14a to 11-14c). Usually, an 0.012, 0.014 and 0.016 NiTi wire, and 0.016 TMA wire are used. A loop is made in a place as close as possible to the bracket on the second premolar. Buccolingually, the position of the loop should be as buccal as possible, since the canines are retracted distally and buccally (Figs 11-15a to 11-15d).



Figs 11-10a,b Partial canine retraction using a lingual arch.



Fig. 11-11 Glass ionomer cement applied to raise the bite.



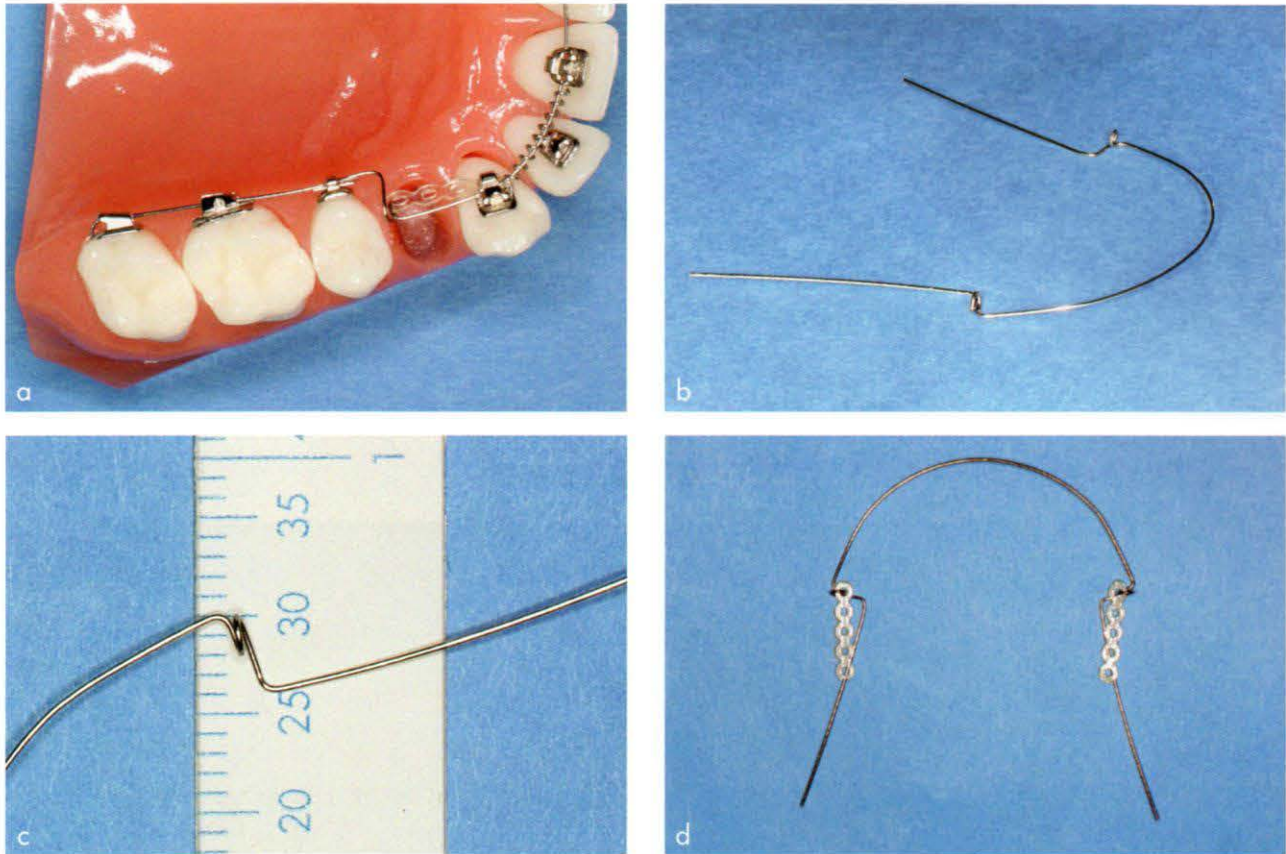
Figs 11-12a,b Anterior leveling.



Figs 11-13a-c Partial canine retraction using a full archwire with loops.



Figs 11-14a-c NiTi coil spring used to actively make space.



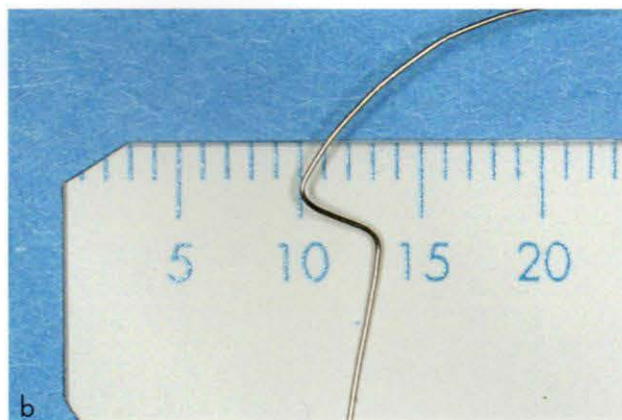
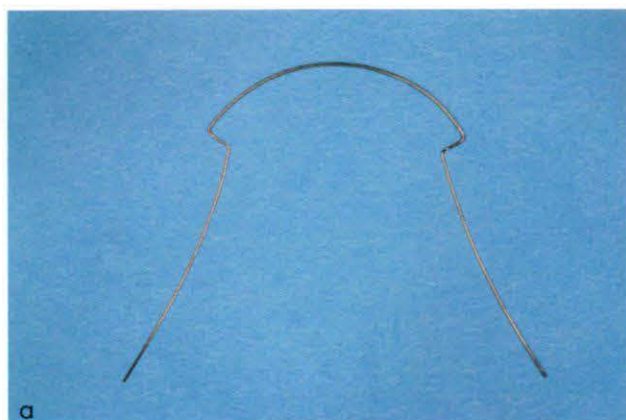
Figs 11-15a-d Partial canine retraction (full archwire with loops).

Anterior Leveling (0.010, 0.012, 0.014, 0.016, 0.016 × 0.016 NiTi wire)

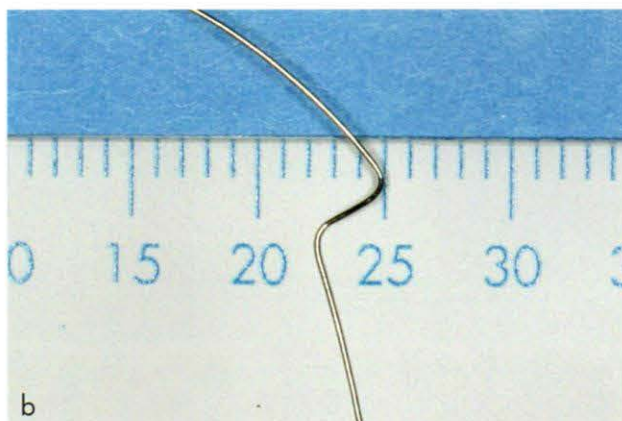
After partial canine retraction is completed, or when the existing crowding is mild, brackets are placed on all teeth and the six anteriors are leveled with full archwires. Since the STb system allows tooth movement with low friction and low force if a wire 0.013 or smaller is used, leveling and rotation correction are achieved very smoothly. Therefore, a wire 0.013 or smaller is used as an initial wire. When rotation is present, it is desirable to correct it actively with power chains (see below).

The form of the leveling archwire is very simple. First, vertical steps for the anterior teeth are not usually added to the maxillary leveling wire.

The posterior part of the wire should not have an inset, and is given a slightly outwardly curved form. The amount of canine inset is determined by the set-up, and it is usually about 4.0 mm (Figs 11-16a and 11-16b). Next, the mandibular leveling wire, like the maxillary leveling wire, is not usually furnished with vertical steps for the anterior teeth. The posterior part is kept straight, ie, without insets or a curve in the arch form. The amount of canine inset is usually about 3.0 mm, about 1.0 mm less than the maxillary inset (Figs 11-17a and 11-17b). In patients with open bite, vertical steps are added to both the maxillary and mandibular leveling arches. In this step, it is important to ensure leveling and rotation correction are achieved.



Figs 11-16a,b The amount of canine inset required in the upper arch.



Figs 11-17a,b The amount of canine inset required in the mandibular arch.

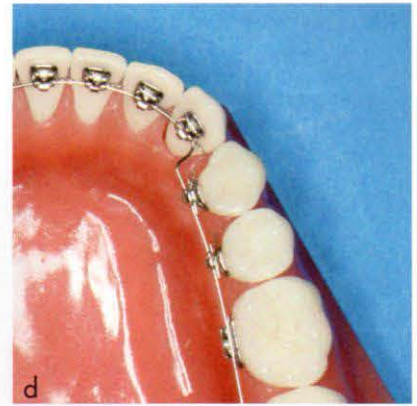
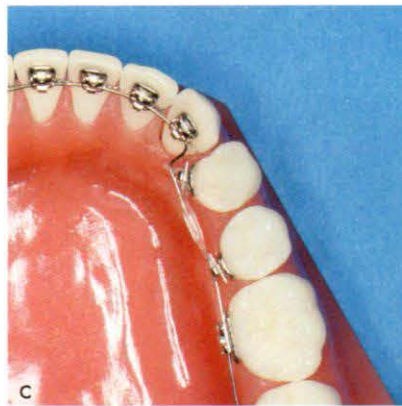
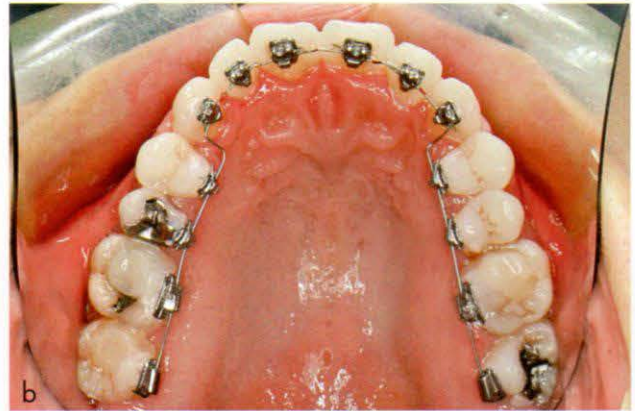
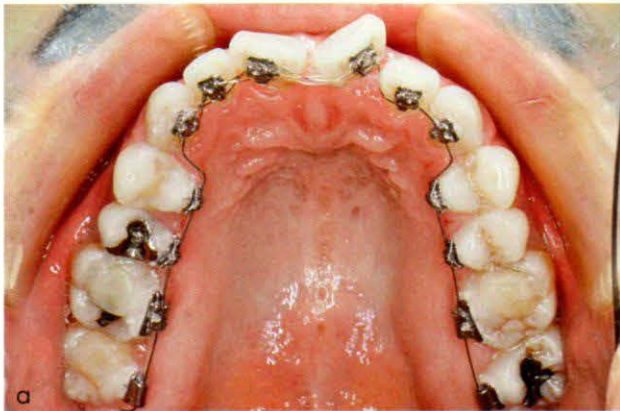
Methods of Rotation Correction

Winging (Figs 11-18a to 11-18d anterior teeth and premolars) When anterior teeth or premolars that are adjacent to each other are rotated in reverse directions, the rotation is actively corrected with power chains extending from one lingual bracket to another.

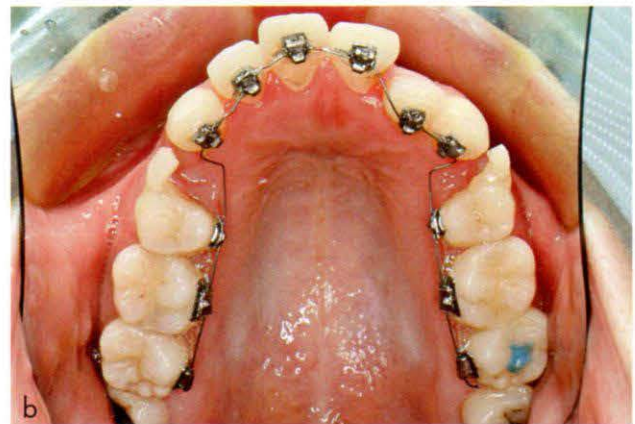
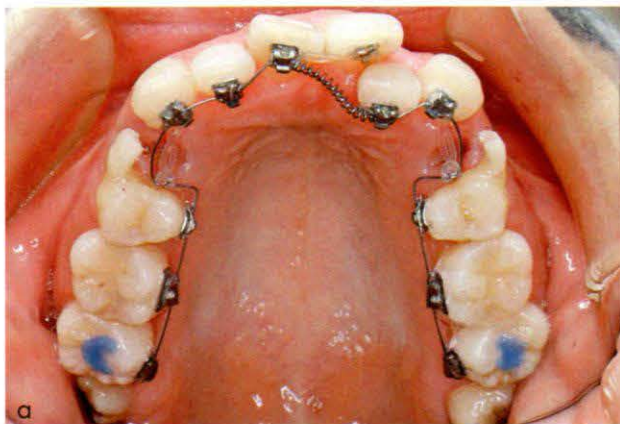
Rotation of anterior teeth (Figs 11-19a to 11-19c) After enough space has been made for rotation correction with the use of open coil springs,

and before the archwire is ligated to the brackets, lingual cleats are bonded on the lingual surfaces of the teeth and power chains are placed as shown in Figure 11-19a to correct the rotation to some extent. Then brackets are placed and the archwire is ligated, and the rotation is fully corrected.

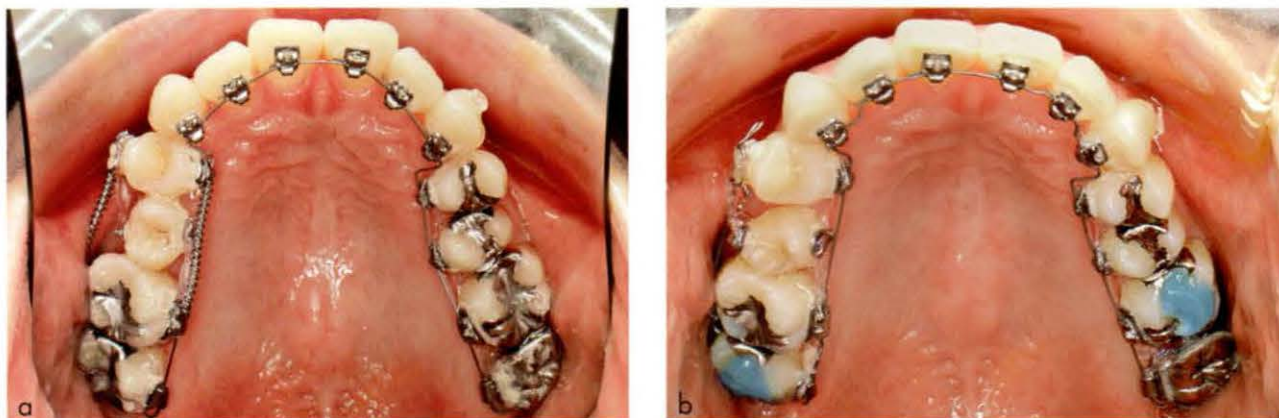
Rotation of premolars (Figs 11-20a and 11-20b) Rotated premolars are corrected with lingual cleats bonded on the lingual surface, lingual buttons bonded on the buccal surface, and power chains placed buccolingually.



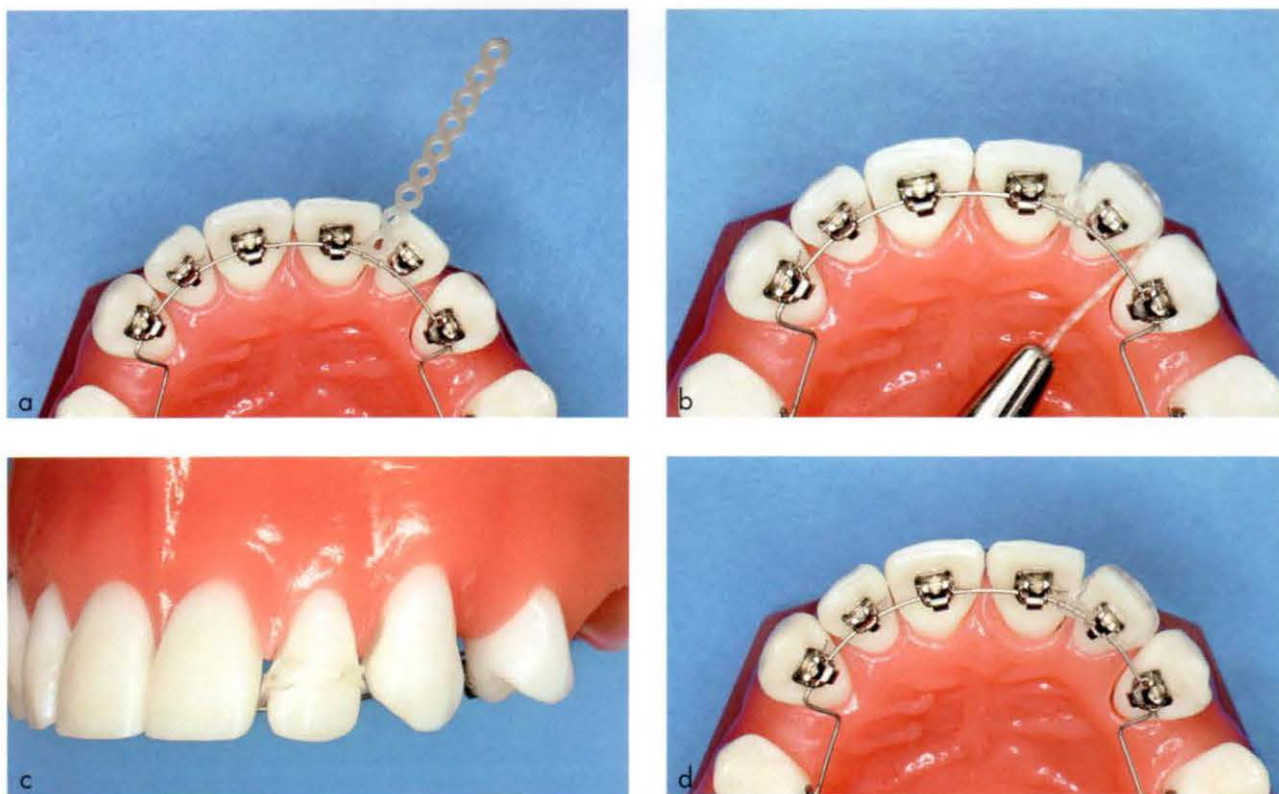
Figs 11-18a-d Derotation of winged incisors and premolars.



Figs 11-19a-c Derotation of rotated and crowded anterior teeth.



Figs 11-20a,b Derotation of the maxillary right second premolar.

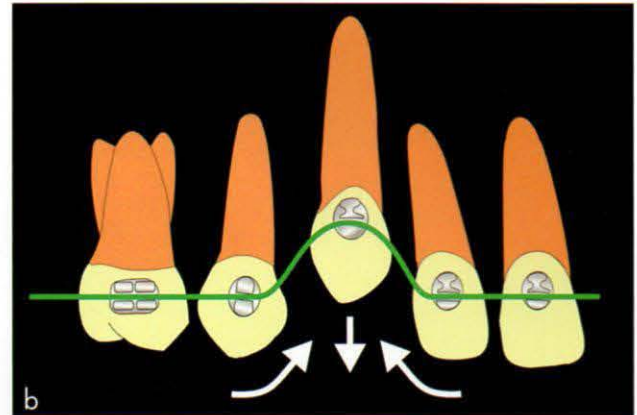
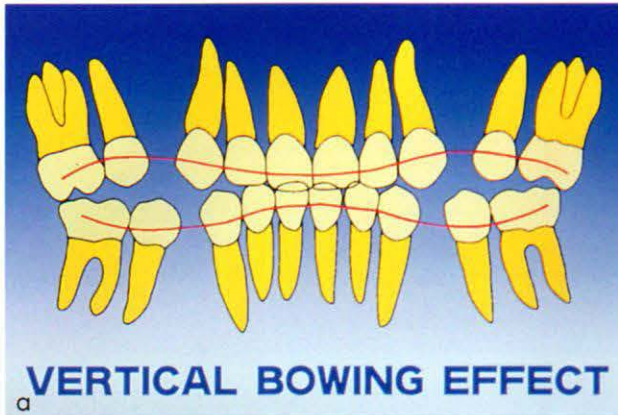


Figs 11-21a-d Smith's rotation tie.

Smith's rotation tie (Figs 11-21a to 11-21d) Smith's rotation tie allows rotation to be corrected without moving the teeth mesially or distally. When this tie is used, however, a space wider than the horizontal width of the rotating tooth should be available.

Precautions in the Leveling Stage

As a vertical bowing effect tends to occur during leveling, due attention should be paid to the position and tipping of individual teeth. Precautions are necessary, particularly in the case of high or distally tipped canines.



Figs 11-22a,b Vertical bowing effect (leveling stage).

High canine In a patient with high canines, during leveling with full archwires when the canines are moved toward the occlusal plane, there is simultaneous tipping – as a countermovement – of the teeth that are mesial and distal to the canine towards it. This creates a lateral open bite. This is followed by forward tipping of the posterior segments as “vertical bowing effect” and lateral occlusal function is impaired, eventually causing anchorage loss (Figs 11-22a and 11-22b). In order to avoid the vertical bowing effect, it is important to guide the canines to the occlusal plane without impairing lateral occlusal function.

A combination of an LA and vertical elastics may be effective. As previously mentioned, an LA allows the canines to be retracted while maintaining lateral occlusal function. Particularly, when the lateral incisors are in crossbite, the correction of crossbite can be done simultaneously with canine retraction (Fig. 11-23). When the STb system is used, high canines are gradually corrected with a low retracting force using low-friction mechanics and vertical elastics, while maintaining lateral occlusal function (Figs 11-24a and 11-24b).

Distally tipped canine After partial retraction of the canines, distal tipping of the canines is seen, particularly when a lingual arch is used. If the distal tipping of the canines is remarkable, leveling with a full arch will produce the vertical bowing effect and anchorage loss will occur (Fig. 11-25). Under such circumstances, an archwire segment may be



Fig. 11-23 Correction of crossbite with a lingual arch

placed temporarily on the buccal side of the canine to instigate uprighting (Fig. 11-26).

Establishment of Torque
(**0.016 × 0.016, 0.018 × 0.018 NiTi wire, 0.0175 × 0.0175 TMA wire, 0.018 × 0.018 β III wire**)

On completion of leveling of the six anterior teeth, establishment of torque of these teeth is always necessary before proceeding with en-masse retraction. If en-masse retraction is done in the presence of insufficient torque in the six anteriors, the teeth with inappropriate torque will serve as anchors, and this may lead to posterior anchorage loss.



Figs 11-24a,b Correction of crossbite with the STb system.

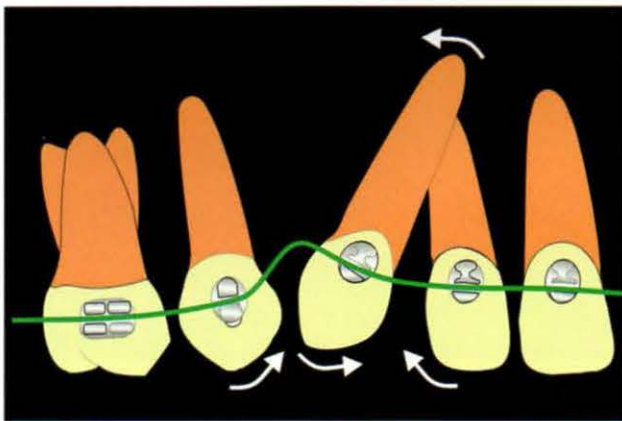


Fig. 11-25 Vertical bowing effect (distally tipped canine).



Fig. 11-26 Upright section (distally tipped canine).

The initial wire used for torque establishment is a 0.016×0.016 NiTi wire, followed by a 0.0175×0.0175 TMA wire and 0.018×0.018 β III wire. If necessary, a 0.018×0.018 NiTi wire can be used in between. If there is no problem with the canine relationship, all six anteriors are ligated together, or power chains are used, to prevent any space from opening. Ligation should not be interrupted where there is an extraction space, to avoid space opening. If the anterior segment is proclined, initially a loop is incorporated in a 0.016 TMA or 0.0175×0.0175 TMA wire to move the teeth lin-

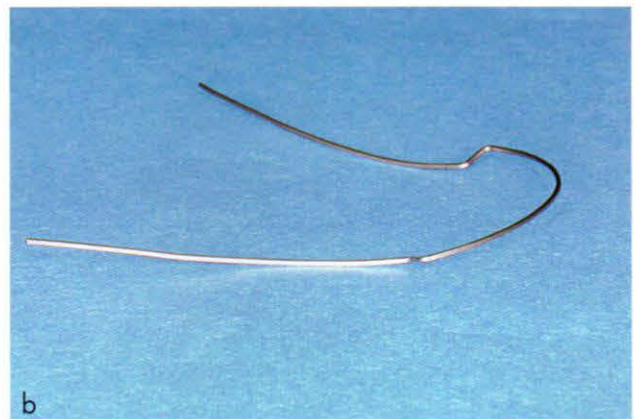
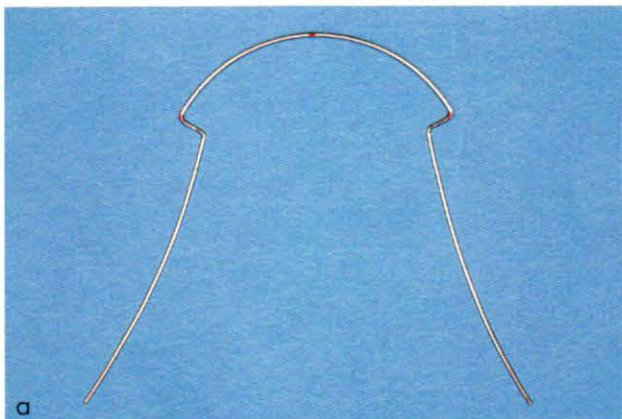
gually for proper torque (Figs 11-27a and 11-27b). The maxillary wire is furnished with a gable bend and a lateral compensating curve (Figs 11-28a and 11-28b). In the mandibular arch, usually no torque is introduced into the archwire (Figs 11-29a and 11-29b).

En-masse Retraction

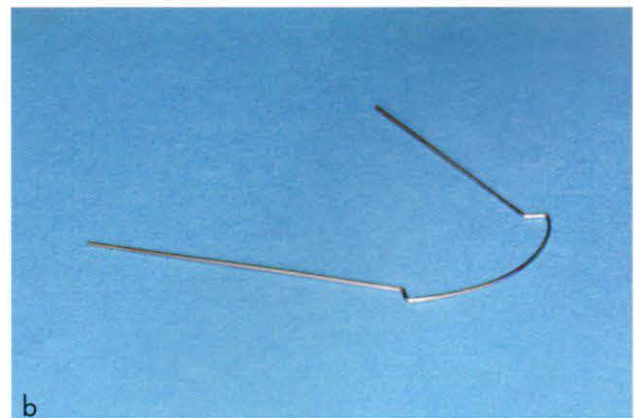
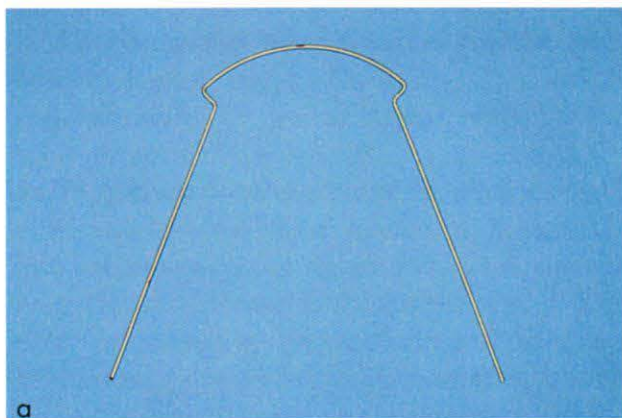
In lingual orthodontic treatment, the six anteriors are retracted together for reasons of esthetics and mechanics. This is called en-masse retraction.



Figs 11-27a,b Establishing torque with loops.



Figs 11-28a,b Establishing torque in the maxillary arch.



Figs 11-29a,b Establishing torque in the mandibular arch.

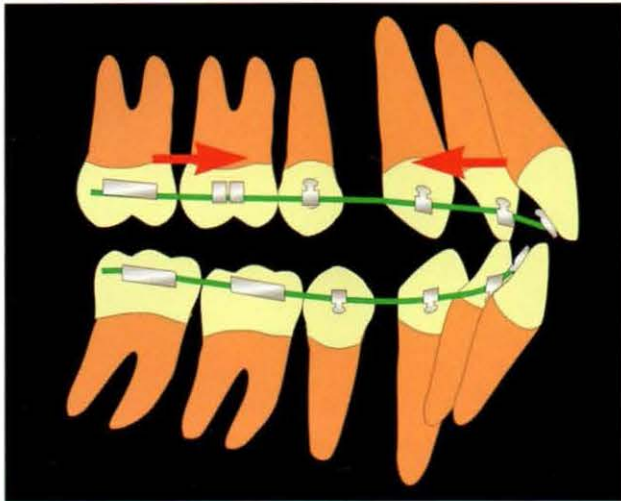


Fig. 11-30 The vertical bowing effect.

Many patients prefer lingual orthodontic treatment for esthetic reasons, because they do not like the space produced between the lateral incisor and the canine after full canine retraction has been done with conventional labial orthodontic treatment. In terms of mechanics, if full canine retraction is used with the lingual technique, the resulting inter-bracket span between the canine and the premolar is very short, and the canine inset on archwire allows only limited activation or sliding.

The Bowing Effect during En-masse Retraction

During en-masse retraction, utmost care should be taken because impairment of lateral occlusal function may cause the posterior teeth to tip forward, leading to anchorage loss. This would result particularly from vertical and transverse bowing effects on the maxillary arch.

Mechanism of vertical bowing effect

When a strong retraction force is applied to the maxillary anterior segment, it tips lingually causing deep bite. As a result, there is development of premature contact between the maxillary lingual bracket and the mandibular anteriors, followed by development of posterior dysfunction, and lateral

Box 11-4 The vertical bowing effect.

1. Retraction force
2. Lingual tipping of anterior teeth
3. Strong contact between bite plane and lower anteriors
4. Posterior disclusion
5. Loss of lateral function
6. Tip - forward of posteriors

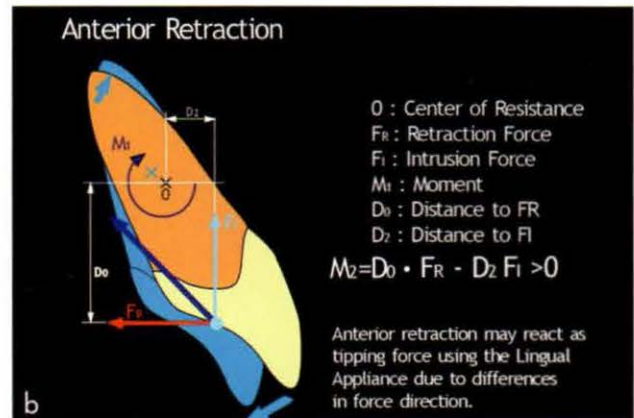
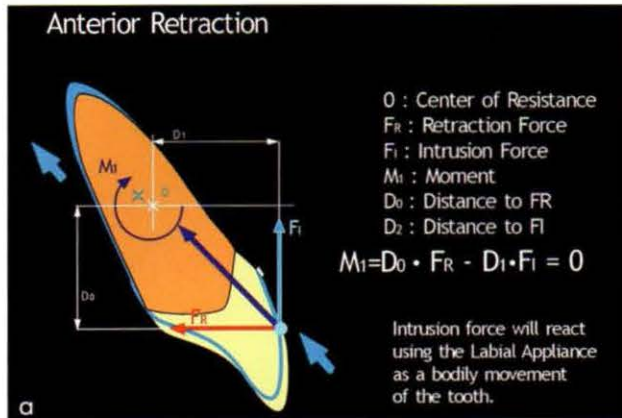
occlusal function is impaired. Then, anchorage loss occurs because the posterior segment tips mesially (Fig. 11-30; Box 11-4). This phenomenon is called the vertical bowing effect.

How to avoid the vertical bowing effect

As mentioned earlier in the chapter, the anterior segment tends to tip labially in lingual orthodontic treatment compared with labial orthodontics (Figs 11-31a and 11-31b). In order to avoid the vertical bowing effect during en-masse retraction, sufficient countermoments should be ensured by reducing the retraction force and adding a gable bend and a compensating curve in the wire. At the same time sufficient root lingual torque should be added to the anterior segment of the archwire (Fig. 11-32). Currently, orthodontic implants are being used to eliminate anchorage loss in the posterior segment that is caused by the vertical bowing effect (see below).

Mechanism of transverse bowing effect

In en-masse retraction with conventional mechanics, the force applied to the posterior teeth causes distal rotation (Fig. 11-33). Distal rotation of the first molar increases the space between the first molar and the second premolar and narrows the space between the first molar and the second molar. This phenomenon is called the transverse bowing effect.



Figs 11-31a,b Production of labial tipping of incisors with the lingual technique.

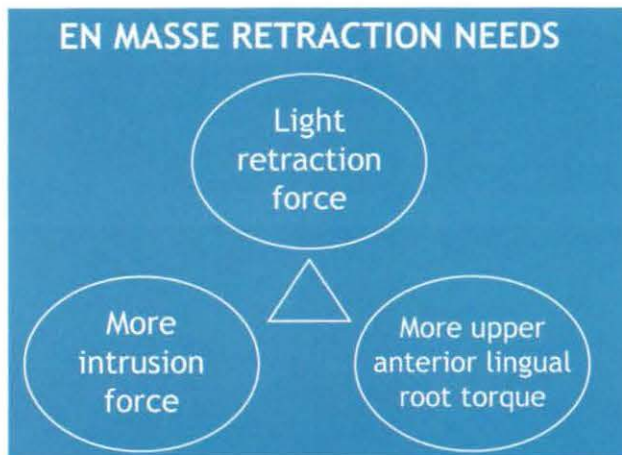


Fig. 11-32 Measures to prevent the vertical bowing effect.

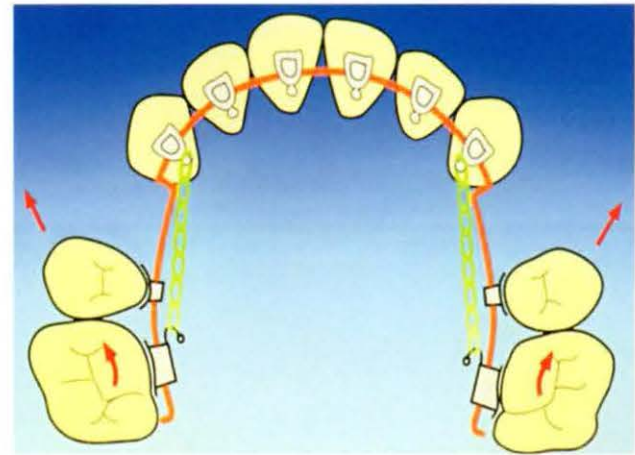
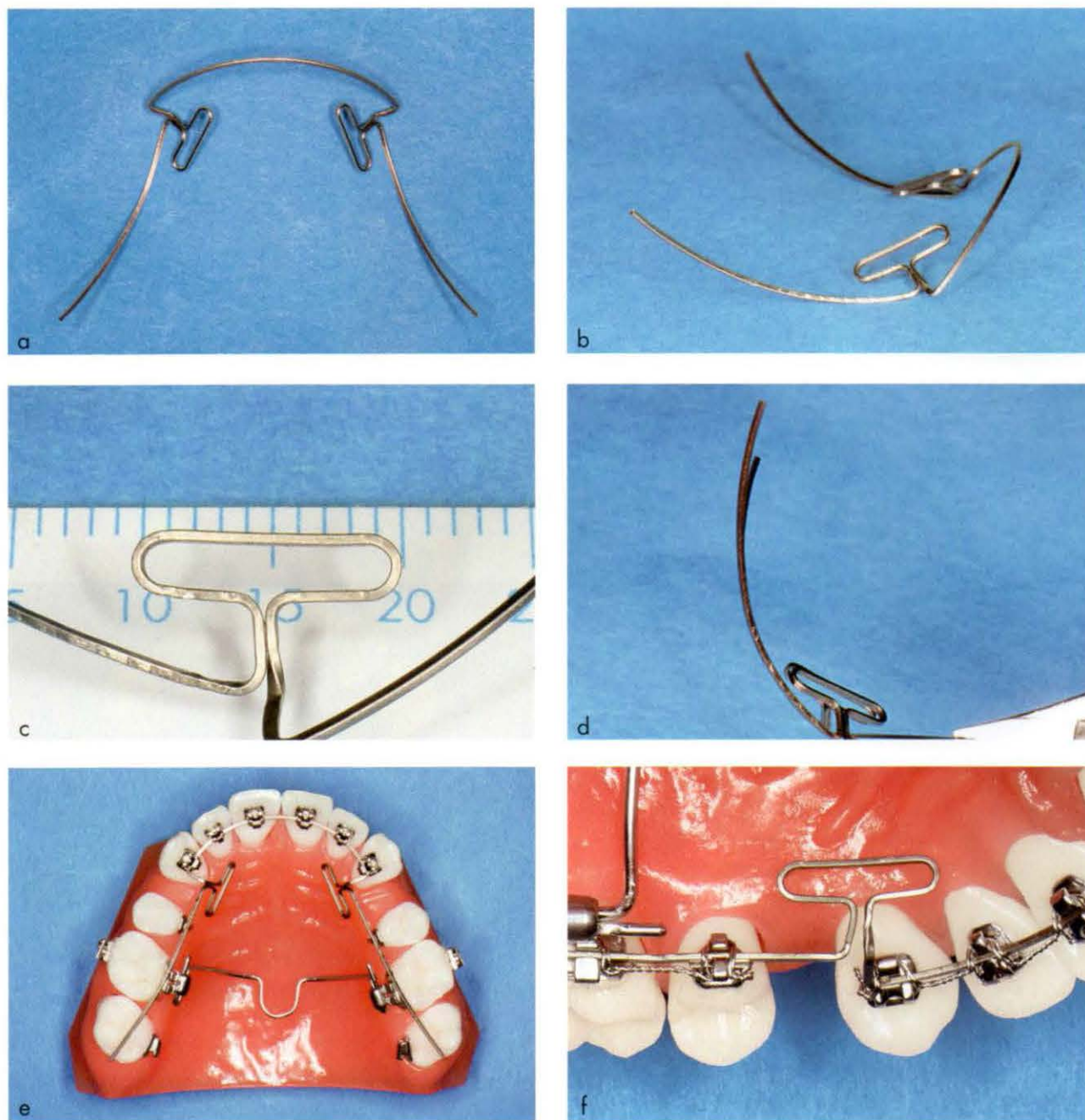


Fig. 11-33 Transverse bowing effect.

How to avoid the transverse bowing effect To avoid the transverse bowing effect, the archwire is curved outward distally. The premolar sections are made slightly narrower, and the second molar sections, both right and left, are made one cusp wider (Fig. 11-34). Also, distal rotation can be avoided with a transpalatal arch placed on the first molar section. The transpalatal arch is indispensable, particularly when headgear is worn, which tends to cause distal rotation of the first molars.



Fig. 11-34 Vertical bowing in both arches.

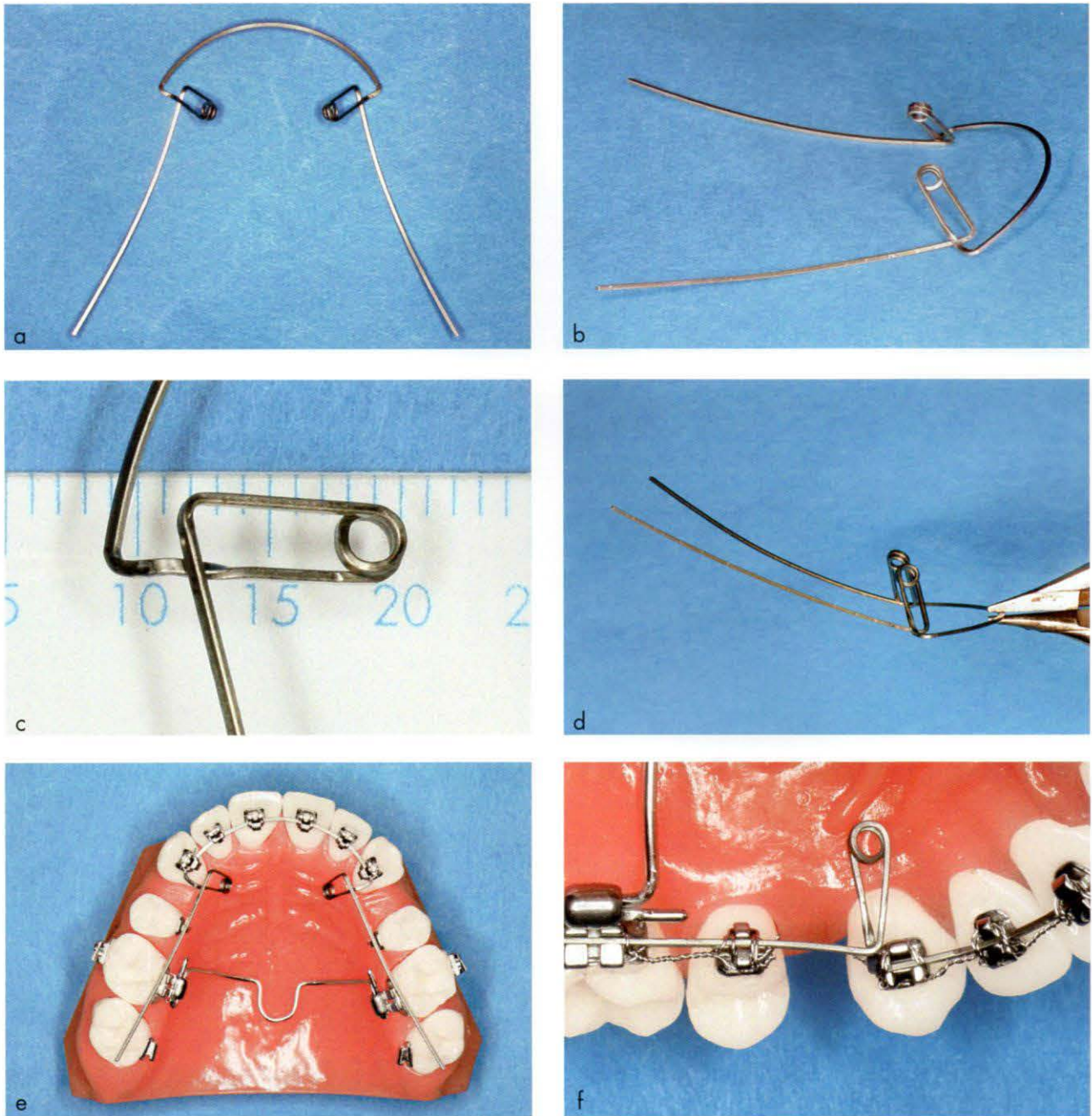


Figs 11-35a-f Loop mechanics with the T-loop.

Mechanics for En-masse Retraction

There are two types of mechanics for en-masse retraction, loop mechanics and sliding mechanics, and along with the use of the recently introduced orthodontic implants, highly stable treatment is possible.

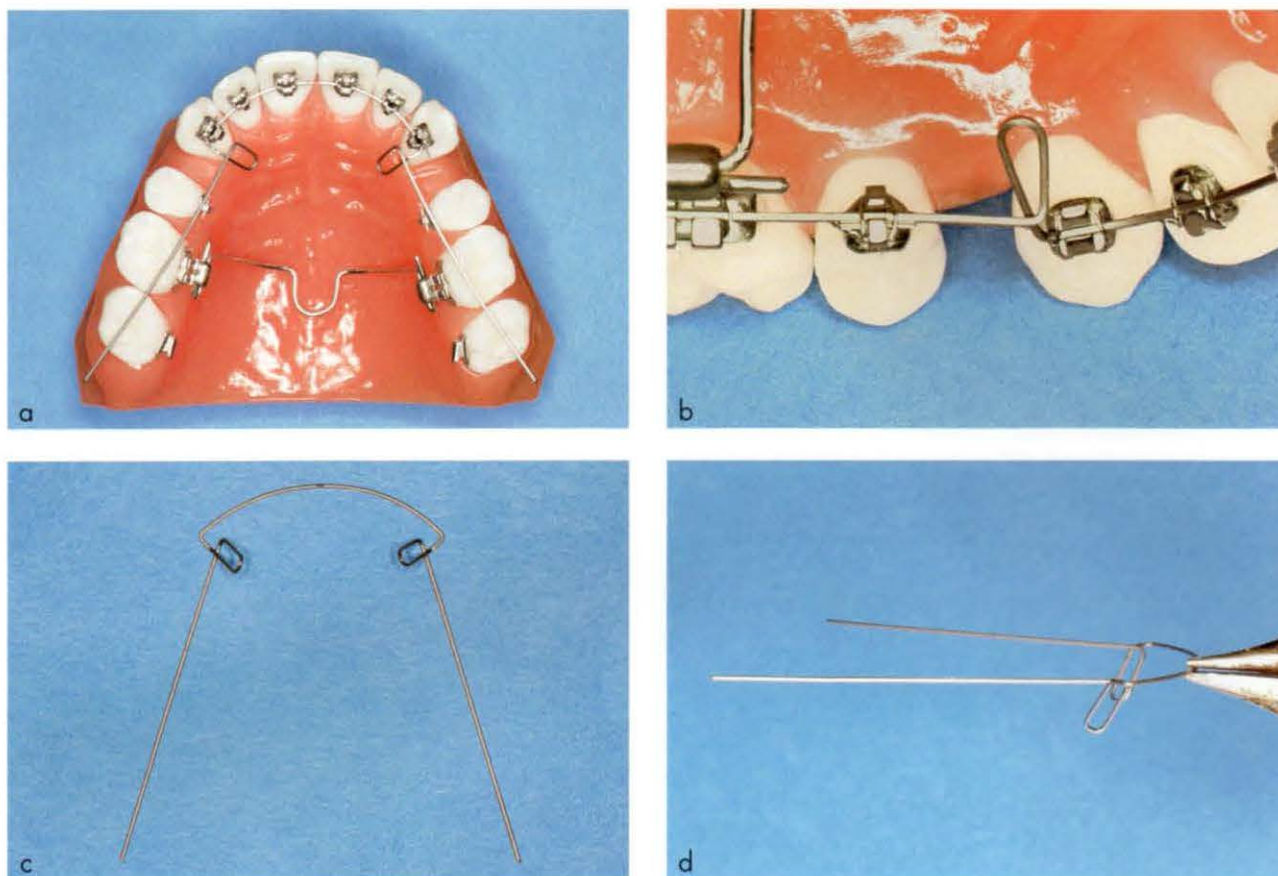
Loop mechanics En-masse retraction with loop mechanics is mainly used in the maxillary arch. Three types of loop are available: T-loop, closing helical loop, and closing loop (Figs 11-35 to 11-37). The characteristics of each loop are shown in Table 11-1. Of the three types of loop, the T-loop allows retraction with the lightest continuous force.



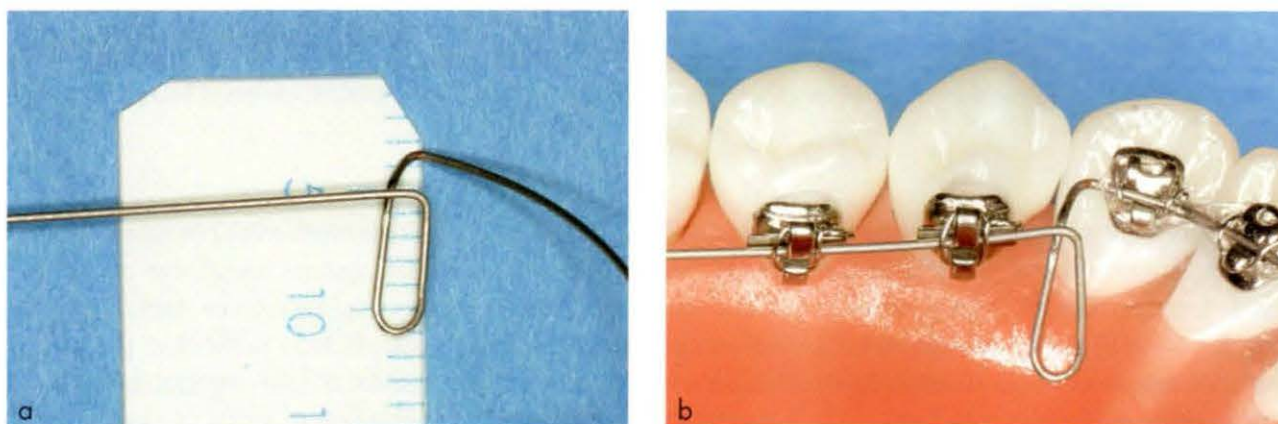
Figs 11-36a-f Loop mechanics with the closed helical loop.

Vertical control is also possible. Therefore, they are used to close a large extraction space while the other two are used to close smaller spaces. The amount of activation is about 1 mm, and activation is done once every 6 to 8 weeks. Also, it is necessary to remove the wire once every 2 to 3 months to ensure appropriateness of the gable bend and com-

pensating curve. Loop mechanics are rarely used in the mandibular arch, except for closure of a minor space or torque establishment in labially tipped mandibular anteriors. In most patients, a 0.0175 × 0.0175 TMA, or 0.016 TMA wire is used for the archwire with closing helical loops or closing loops (Figs 11-38a and 11-38b).



Figs 11-37a-d Loop mechanics with the closing loop – I.



Figs 11-38a,b Loop mechanics with a closing loop – II.

Table 11-1 Characteristics of maxillary archwires used in loop mechanics.

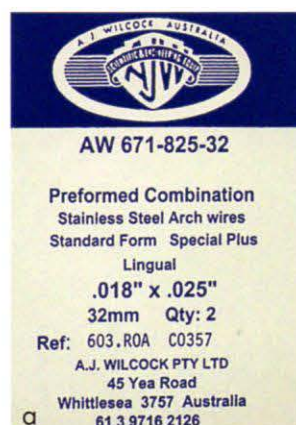
	T-loop	Closed helical loop	Closing loop
Wire size	0.017 × 0.025 TMA	0.017 × 0.025 TMA	0.0175 × 0.0175 TMA
Bite raising	○	Δ	Δ
Torque control	○	Δ	Δ
Indications	Patients requiring bite opening and torque control, with large spaces to close	Patients with proclined anterior teeth or open bite who can afford tipping of anterior teeth lingually	Patients with lingually tipped teeth and need for space closure
Loop configuration	About 5 mm high and 10 mm wide with 45 degrees gable bends	About 9 mm high and 3 mm wide with 30 degrees gable bends	About 9 mm high and 3 mm wide with 30 degrees gable bends
Posterior arch form	• Buccal crown torque • Curved arch form • Compensating curve	• Buccal crown torque • Curved arch form • Compensating curve	• Buccal crown torque • Curved arch form • Compensating curve

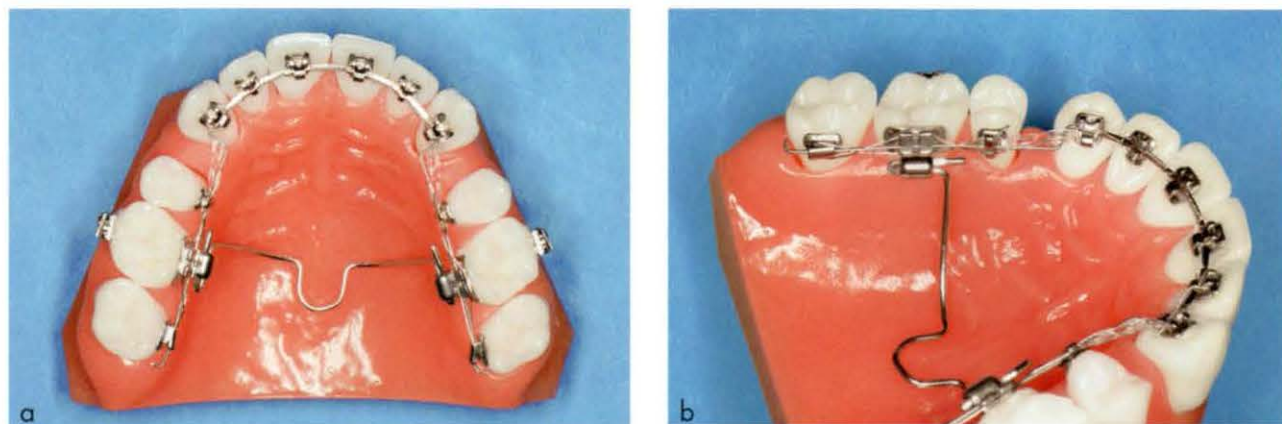
○: Achievable with this wire configuration.

Δ: Difficult to achieve with this wire configuration.

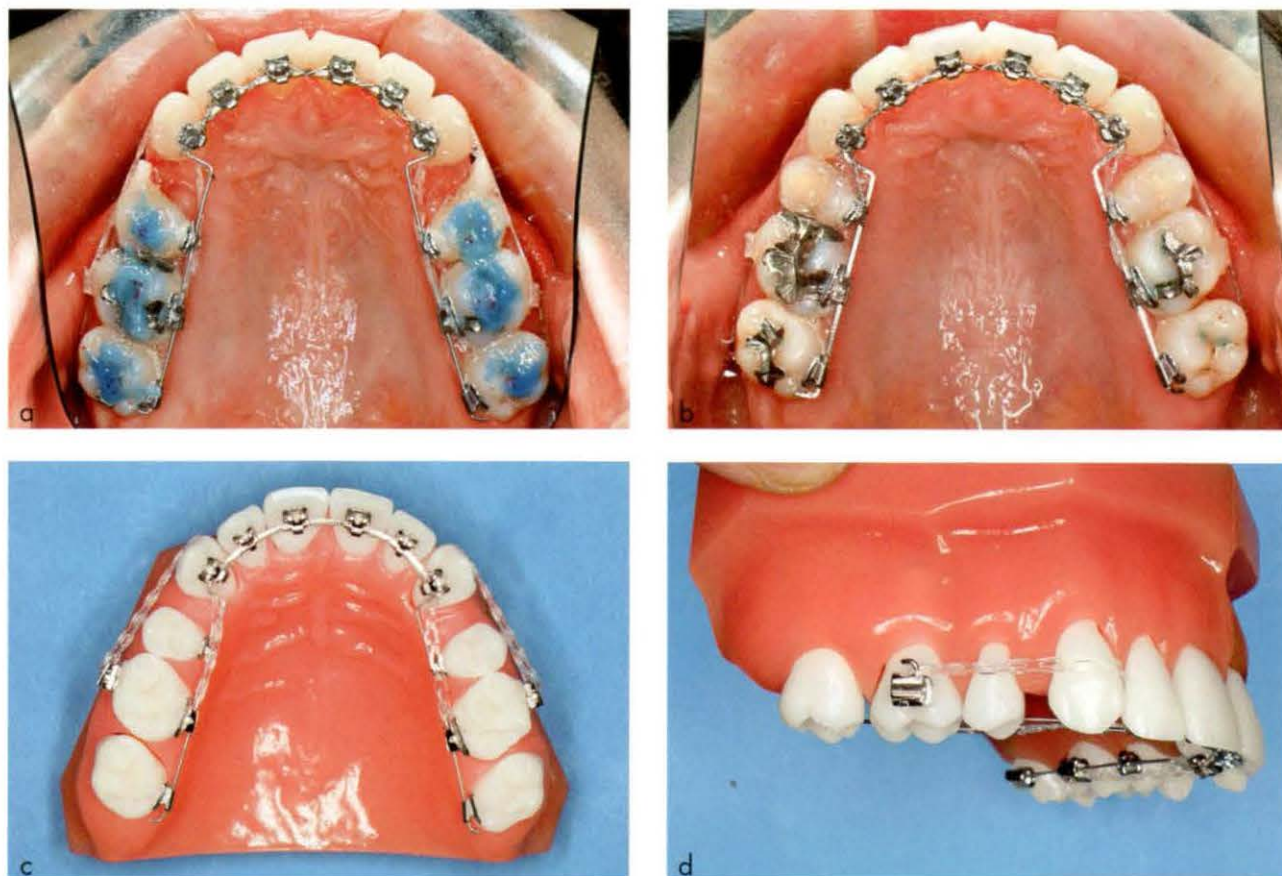
Sliding mechanics: maxillary arch A preformed combination wire, with a rectangular anterior portion and a round posterior, is commonly used for efficient sliding with reduced friction (Figs 11-39a and 11-39b). Its anterior portion measures 0.017 × 0.025 and its posterior portion is 0.017. A gable bend and a compensating curve are incorporated in the wire to avoid the bowing effect (see Figs 11-28a and 11-28b). En-masse retraction is done as shown in Figs 11-40 and 11-41. In one method (Figs 11-40a and 11-40b) en-masse retraction is performed with the six anterior teeth and the right and left posterior teeth ligated together to make one segment

each; a power chain is placed from the premolar to the lateral incisor or to the canine. In another method (Figs 11-41a to 11-41d), en-masse retraction is carried out with the six anterior teeth ligated together, with power chains placed buccally and lingually from the canine to the first molar. In this case, the lingual power chain is engaged in the canine bracket to prevent it from coming off or encroaching on the gingiva (Fig. 11-42). This is called "circular elastic". The second method is beneficial because buccolingual retraction is not likely to produce the transverse bowing effect, although the power chain is visible on the buccal surface.

**Figs 11-39a,b** Preformed combination wire (AJ Wilcock, Australia).



Figs 11-40a,b Maxillary archwire for sliding mechanics.



Figs 11-41a-d Maxillary archwires being used for sliding mechanics.



Fig. 11-42 Power chain engaged in the canine bracket in the maxilla.

Sliding mechanics: mandibular arch En-masse retraction in the mandibular arch is done usually with sliding mechanics. A 0.016 × 0.022 stainless steel (SS) wire is used. Since the bowing effect rarely occurs in the mandibular arch, the wire is not furnished with any gable bend, compensating curve, or anterior vertical step, and it is used as a flat archwire. En-masse retraction is carried out in the mandibular arch in a similar fashion to that in the maxillary arch, and circular elastics are often used (Figs 11-43a to 11-43c).

To achieve en-masse retraction with sliding mechanics efficiently, friction should be reduced as much as possible. For that purpose, it is necessary to use pre-formed combination wires or low-friction systems such as the "Frictionless Mechanics" system designed by Dr. Fillion (Figs 11-44a to 11-44c). Care should be taken not to create a bowing effect, which is likely to occur with higher retraction forces.



Figs 11-43a–c Mandibular archwire for sliding mechanics.



Figs 11-44a-c Low-friction system (designed by Dr. Didier Fillion).

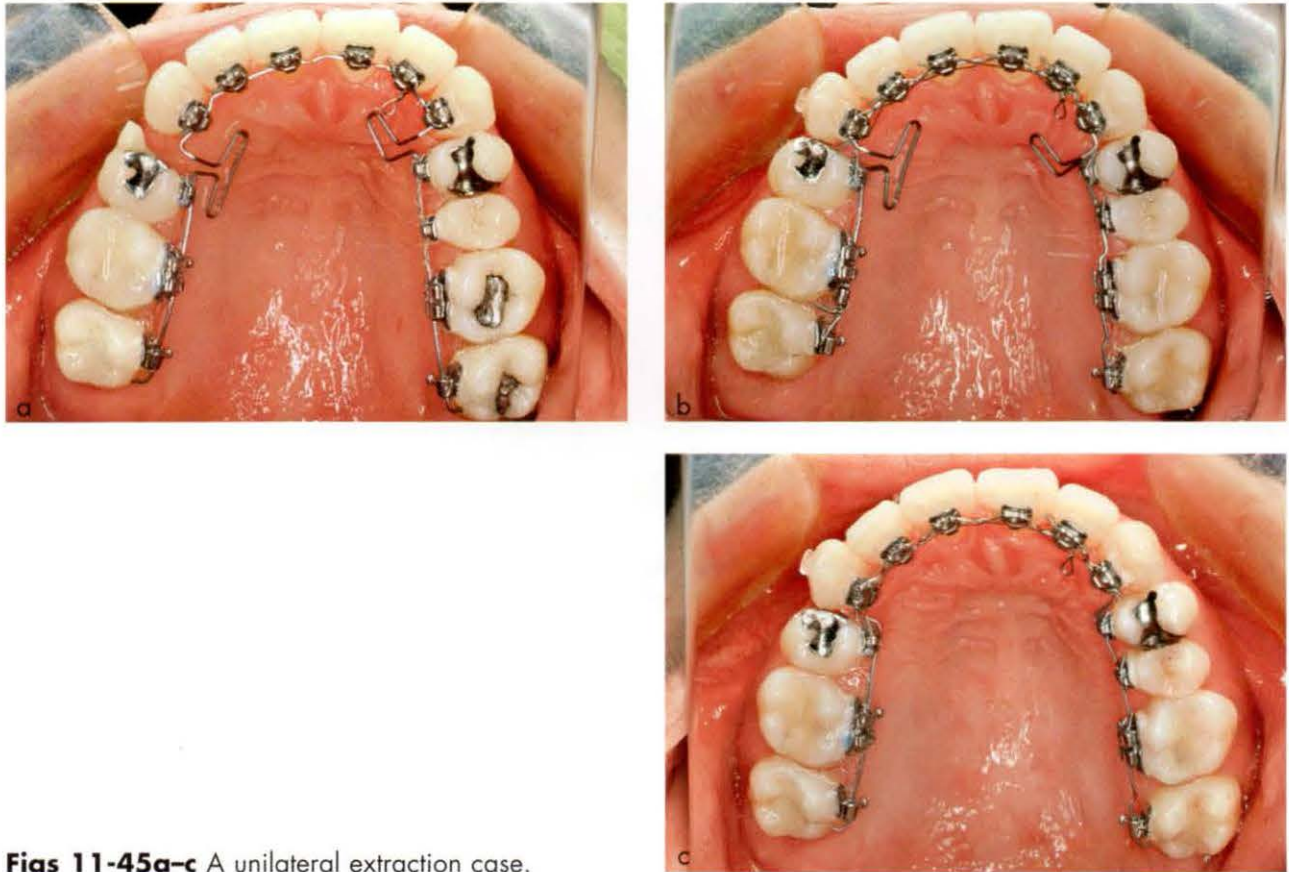
Comparison between loop mechanics and sliding mechanics

Table 11-2 shows the advantages and disadvantages of loop mechanics and sliding mechanics. It is important to have a thorough knowledge of their characteristics and make use of the mechanics that suit the situation best. In particular, when sliding mechanics are used after unilateral extraction, friction is greater because of the deforming force applied to the wire, and it takes time to close the space. In contrast, with loop mechanics, since the loop on the nonextraction side serves as a hinge and there is no friction, the space is closed efficiently (Figs 11-45a to 11-45c).

Anchorage Control in En-masse Retraction

In lingual orthodontic treatment, anchorage in the mandibular arch is far stronger than in the maxillary arch. For that reason, anchorage needs to be reinforced specifically in the maxillary arch. Table 11-3 shows methods of maximum, moderate, and minimum anchorage in maxillary loop mechanics and sliding mechanics.

For maximum anchorage, a first choice is orthodontic implants (see below). When orthodontic implants are contraindicated, headgears, transpalatal arches, Class II elastics, and stabilized sectional archwires on the buccal surface of the posterior segment are used as reinforced anchorage (Figs 11-46a and 11-46b). For moderate anchorage,



Figs 11-45a–c A unilateral extraction case.

Table 11-2 Comparison between loop mechanics and sliding mechanics.

	Loop mechanics	Sliding mechanics
Wire friction	○	△
Anti-tipping bend	Easy to place	• Need to minimize wire friction • Limitation in placing bends
Control of retraction force	• Easy to visualize amount of loop • Activation done by the clinician, thus easy to control	• Difficult to quantify level of force • Power chain used to apply force, thus harder to control
Asymmetric or unilateral extraction cases	○	△
Bite opening control	○	△
Discomfort	Complex form, causing much discomfort	Simple form giving little discomfort
Wire bending	△	○

○: Achievable with these mechanics.

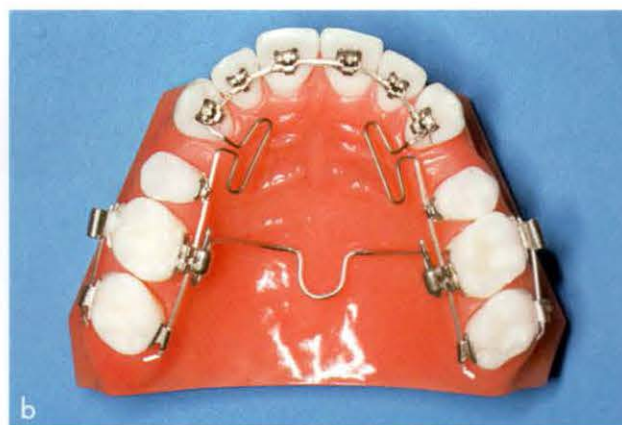
△: Difficult to achieve with these mechanics.

Table 11-3 Anchorage control in the maxillary arch.

	Loop mechanics	Sliding mechanics
Maximum	• Implant • TPA • Headgear or inner bow • Class II elastics • Sectional archwires for added stability • Figure of eight tie • TPA and headgear	• Implant • TPA • Headgear or inner bow • Class II elastics • Sectional archwires for added stability • 5-7 laceback tie • 2-5 power chain • TPA and headgear
Moderate	• Class II elastics • 5-7 figure of eight tie	• Class II elastics • 5-7 laceback tie • 2-5 power chain
Minimum		• 4-4 figure of eight tie • 3-6 circular elastics • Class III elastics

TPA, transpalatal anchorage.

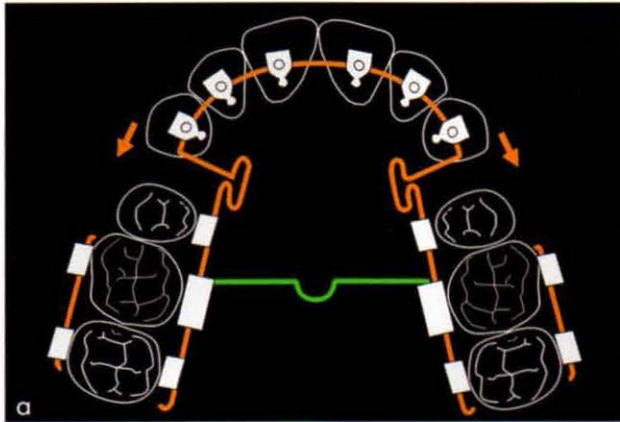
5-7, from second premolar to second molar; 2-5, from lateral incisor to second premolar; 4-4, from first premolar on one side of the arch to the first premolar on the other side of the arch; 3-6, from canine to first molar.

**Figs 11-46a,b** Anchorage control with loop mechanics in the maxillary arch.

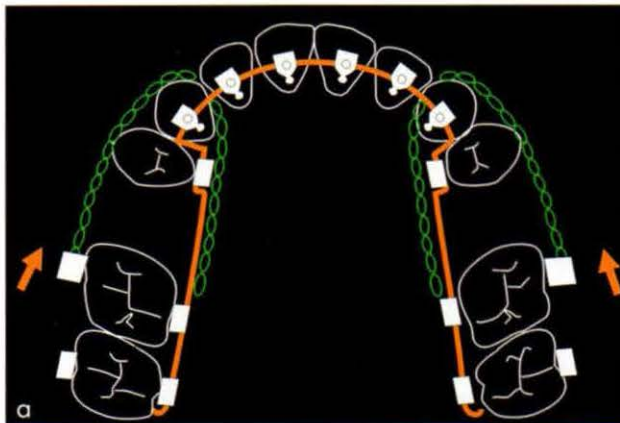
transpalatal arches (Figs 11-47a and 11-47b) and Class II elastics are used. For minimum anchorage, the maxillary second premolars are extracted, and sliding mechanics, circular elastics, and Class III elastics are used in combination (Figs 11-48a and 11-48b). Methods of maximum, moderate, and minimum anchorage in the mandibular arch are shown in Table 11-4.

Anchorage in the mandibular arch is remarkably strong because of the morphology of the alveolar bones and biomechanics peculiar to lingual ortho-

dontics. Therefore, it is difficult to move posterior teeth mesially, and mandibular anterior teeth are likely to tilt lingually. Hence, in particular, in patients with Angle Class II malocclusion being treated with extractions in the mandibular jaw, the key is how to efficiently achieve mesial movement of the posterior segments. To actively move molars mesially, it is necessary to place an orthodontic implant in the anterior part of the mandible for use as anchorage (Figs 11-49a and 11-49b).



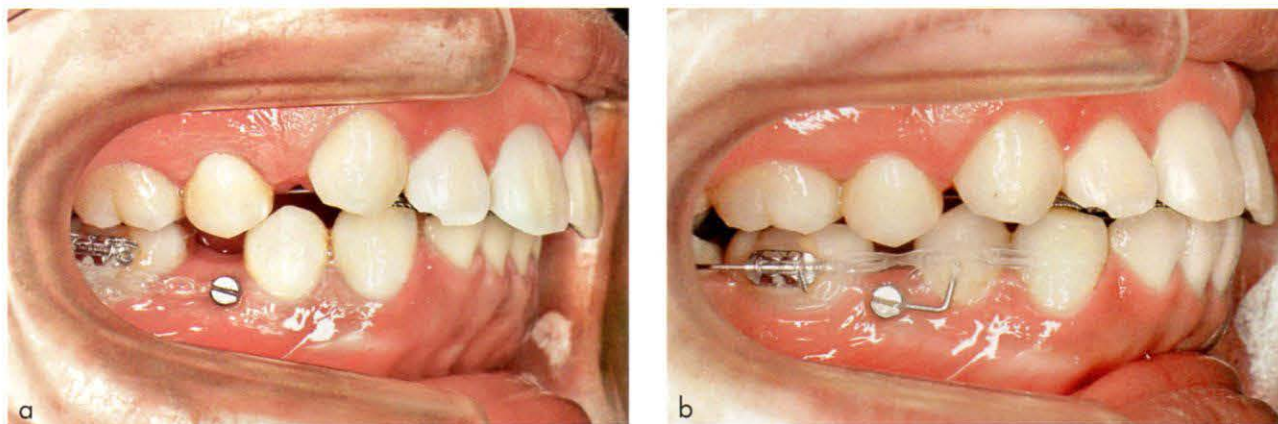
Figs 11-47a,b Anchorage control with loop mechanics in the maxillary arch (moderate anchorage).



Figs 11-48a,b Anchorage control with loop mechanics in the maxillary arch (minimum anchorage).

Table 11-4 Anchorage control during sliding mechanics in the mandibular arch.

	Moderate	Minimum (second premolar extraction case)
3-3 figure of eight tie	3-3 figure of eight tie	4-4 figure of eight tie
5-7 laceback tie	5-7 figure of eight tie	
2-5 power chain (lingual side only)	Six 3-6 circular elastics	Six 3-6 circular elastics and implant anchorage



Figs 11-49a,b Anchorage control with loop mechanics in the mandibular arch (minimum anchorage).

En-masse Retraction with Orthodontic Implants

Advantages of Orthodontic Implants

As mentioned previously, when en-masse retraction is done with maximum anchorage, headgears, Class II elastics, or transpalatal arches, which require patient cooperation and compliance, are indispensable. Nowadays, orthodontic implants are increasingly used to ensure more reliable en-masse retraction with maximum anchorage, even without patient cooperation. In addition, vertical and transverse bowing effects are unlikely to occur because

the posterior segment does not serve as anchor for anterior retraction (Box 11-5).

En-masse Retraction Mechanics and Biomechanics with Implants

Commonly used implants in lingual orthodontics are of the miniscrew type. Presented below are four methods of en-masse retraction with miniscrews that work efficiently. There are differences in the biomechanics between the methods and the one that best suits the situation should be selected (Table 11-5).

En-masse retraction with sliding mechanics, with miniscrews implanted in the interalveolar septum on the palatal side (Figs 11-50a to 11-50d)

This is the most commonly used type of en-masse retraction with miniscrews. Usually, for anatomic reasons, a miniscrew is implanted between the second premolar and the first molar on both sides of the maxillary arch. Closed coils or power chains are placed on the power arms attached from the archwire engaged in the anterior teeth to the miniscrews, and en-masse retraction is done with sliding mechanics. A preformed combination wire is used to minimize friction (see Figs 11-39a and 11-39b). The wire is furnished with a gable bend to maintain the torque of the maxillary anterior teeth (Fig. 11-51).

Box 11-5 Advantages of orthodontic implants.

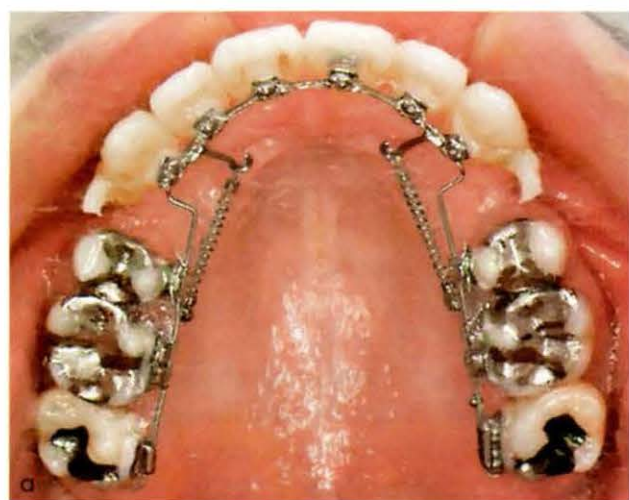
- Provide absolute anchorage
- No need for cooperation of patient
(Head gear, Class II elastics)
- Simple technique of surgery with mini-screw
- Simple mechanics of retraction
- Bowing effect does not occur

Table 11-5 Comparison between the different methods of en-masse retraction.

	Type 1	Type 2	Type 3	Type 4
Wire size	0.017 × 0.025 or 0.018 × 0.025 Combination wire	0.017 × 0.025 or 0.018 × 0.025 Combination wire	0.017 × 0.025 or 0.018 × 0.025 Combination wire	0.017 × 0.025 TMA T-loop
Wire friction	Δ	Δ	Δ	○
Bite raising	Δ	○	Δ	○
Torque control	Δ	Δ	Δ	○
Occlusal function	Δ	○	○	○

○: Achievable with this wire configuration.

Δ: Difficult to achieve with this wire configuration.

**Figs 11-50a-d** En-masse retraction with orthodontic implants in the posterior interdental bone on the palatal side.

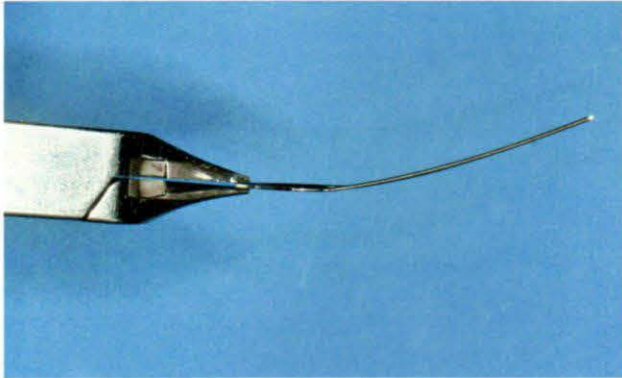


Fig. 11-51 A gable bend is added to the preformed combination wire to maintain the torque of the maxillary anterior teeth.

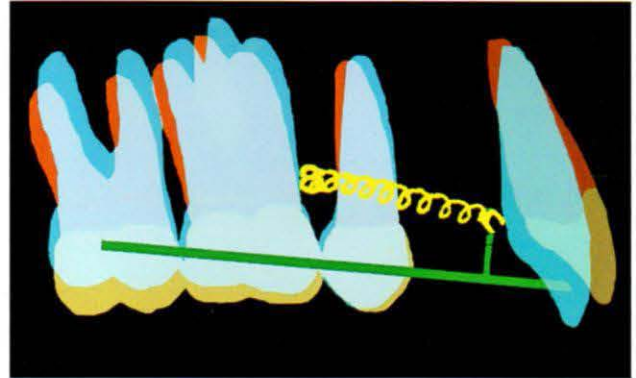


Fig. 11-52 Occlusal plane changes and posterior occlusion opening with high forces used for retraction.

This procedure may induce lingual tipping of the maxillary anteriors and a deep bite, particularly when the retraction force is strong. In addition, the maxillary posterior teeth may intrude, and posterior disclusion tends to occur (Fig. 11-52). Therefore, this procedure is indicated for patients with open bite, in whom the maxillary anteriors are proclined, or in patients with a shallow bite. It is not indicated for patients with deep bite, such as those with Angle Class II, division 2 malocclusion.

En-masse retraction with sliding mechanics, with miniscrews implanted in the median palatal suture (Figs 11-53a to 11-53d) A miniscrew is implanted in the median palatal suture, corresponding to the area between the second premolars. A closed coil or power chain is placed from the miniscrew to the bracket or power arm attached to the archwire engaged in the anterior teeth. Then, en-masse retraction is done with sliding mechanics. The miniscrew is implanted more mesially if a stronger intrusive force is desired, and more distally if a stronger retractive force is desired. This procedure allows retraction without deepening of the bite with the posterior teeth maintained in

stable condition, because it is possible to apply an intrusive force simultaneously with a retractive force (Fig. 11-54). However, it takes time for retraction because power components are divided for intrusion. This procedure is indicated for patients with a normal to deep bite, but not for patients with an open bite.

En-masse retraction with sliding mechanics, with miniscrews implanted on both buccal and lingual aspects of the inter-alveolar septum (Figs 11-55a to 11-55d)

This is a modification of the first method described above. When the volume of the alveolar bone buccolingually is sufficient, a miniscrew is implanted on both the buccal and lingual sides between the alveoli of the second premolar and the first molar. Retraction is done with circular elastics. Preferably, the heads of the miniscrews on both sides are of the same height. Circular elastics used in this procedure allow very efficient retraction, although care should be taken because the retractive force tends to be stronger. Indications and contraindications are the same as for the first method described above.



Figs 11-53a-d En-masse retraction with orthodontic implants (midpalatal suture).

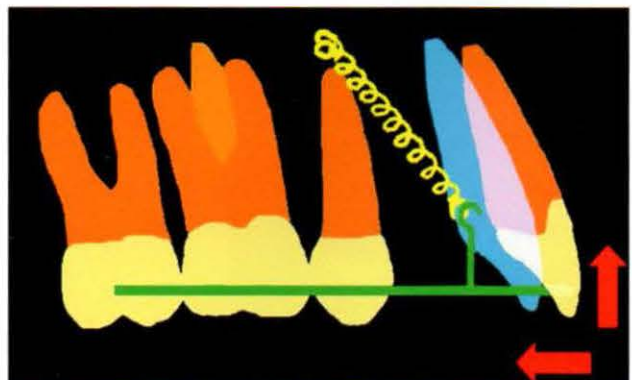


Fig. 11-54 Posterior occlusion is stable.



Figs 11-55a-d En-masse retraction with orthodontic implants (posterior interdental bone on the buccal and palatal sides).

En-masse retraction with loop mechanics, with a miniscrew implanted in the interalveolar septum on the palatal side (Figs 11-56a to 11-56d) A miniscrew is implanted the same as in the first method above, and loop mechanics are used. The retraction loop is activated through ligation of the miniscrew and the hook on the retraction wire (Figs 11-57a and 11-57b). As mentioned previously, compared with sliding mechanics, loop mechanics facilitate control of retraction and intrusion without friction, having more advantages for retraction (see Table 11-2). Generally, an 0.017×0.025 TMA wire with T-loops is used (see Figs 11-35a to 11-35f). This procedure is indicated for almost all patients.

Detailing

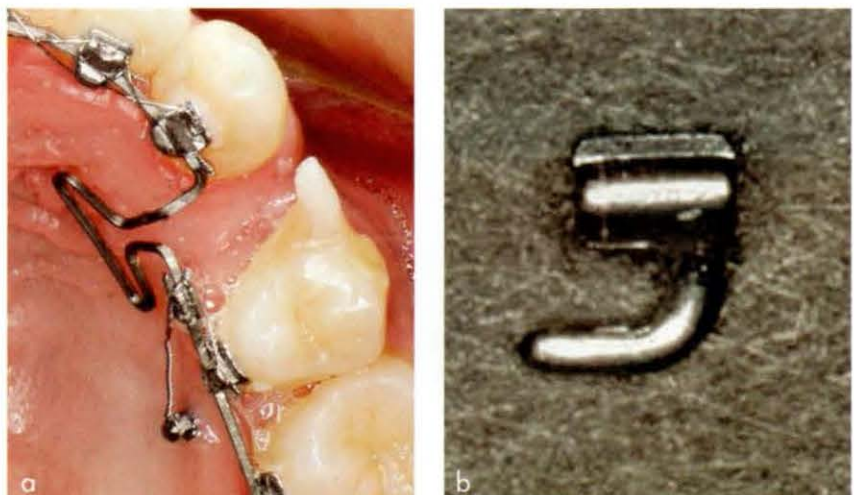
In the detailing stage, coordination of the maxillary and mandibular arches and fine adjustment of individual teeth are done. A 0.016 or 0.0175×0.0175 TMA wire is used in anticipation of settling of the occlusion under natural forces of occlusion. The shape of the wire is almost the same as the jig used on the set-up model, and usually provided with an anterior step and inset between the premolar and molar (Figs 11-58 to 11-60).

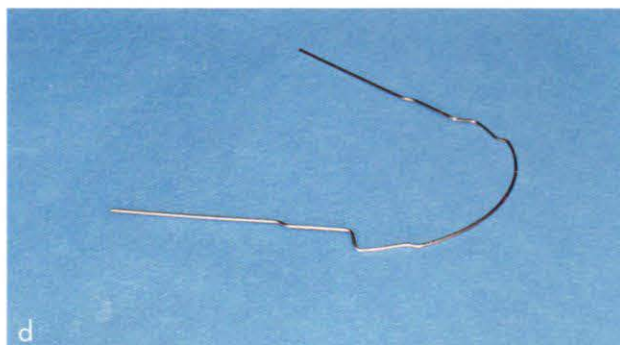
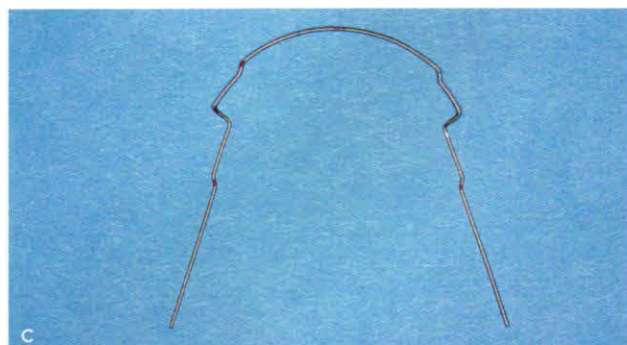
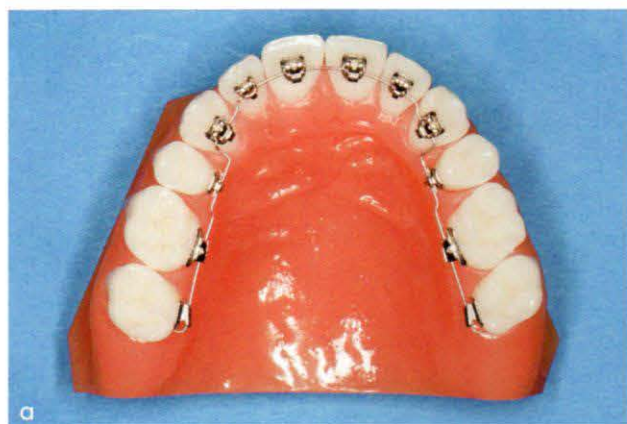
In this stage of treatment, often the wire has a small step, torque, or in-out incorporated. However, since short inter-bracket spans may produce strong orthodontic force in lingual orthodontics, loops are



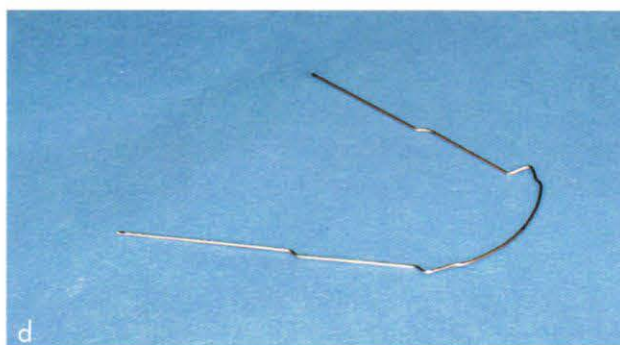
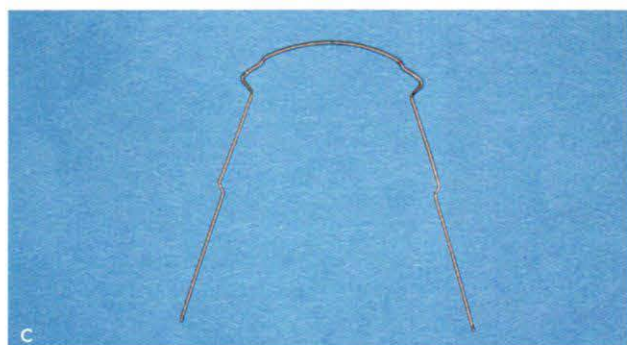
Figs 11-56a-d Loop mechanics with orthodontic implants as anchorage.

Figs 11-57a,b Ligation of the orthodontic implants and the hook on the retraction wire.





Figs 11-58a-d Ideal maxillary arch.



Figs 11-59a-d Ideal mandibular arch.



Fig. 11-60 Arch coordination (ideal arch).

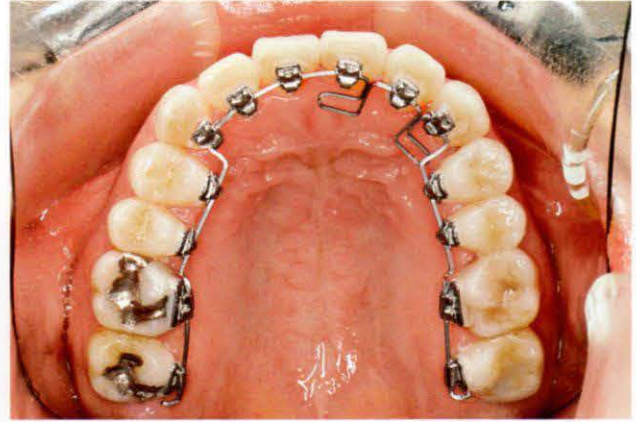
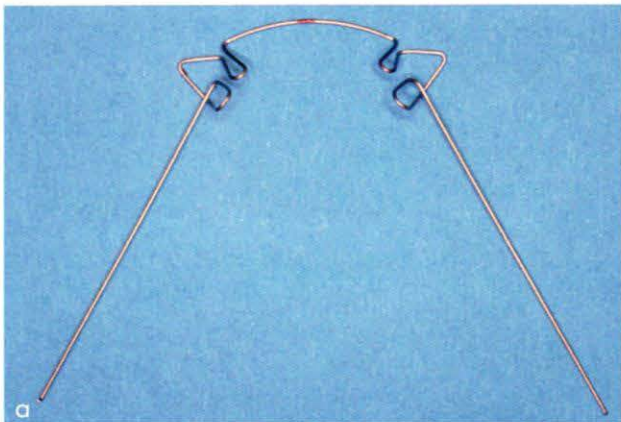
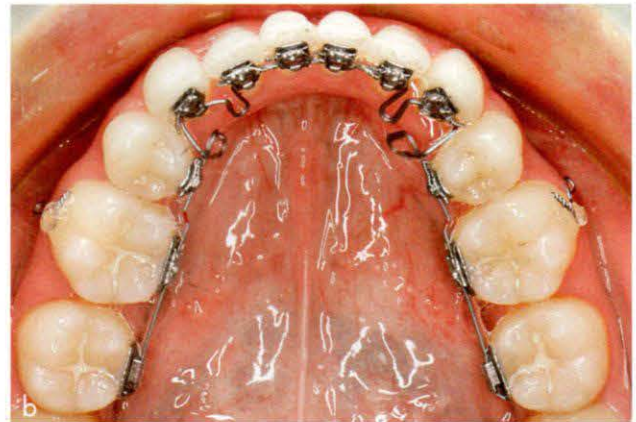


Fig. 11-61 Detailing (torque correction).



Figs 11-62a,b Detailing (rotation correction).



incorporated in the wire mesial or distal to the tooth requiring rotation or torque correction, and treatment is done with light force. Figure 11-61 shows L-loops for correction of torque of the lateral incisors. The loops in Figs 11-62a and 11-62b are used for correction of distal rotation of the canine. In lingual orthodontic treatment, such types of loop are frequently used during detailing because distal rotation of the canine usually occurs after retraction.

Clinical Keys

Esthetic Pontic

For esthetic reasons, patients who undergo lingual orthodontic treatment are often nervous about the space visible after extraction. An esthetic pontic can be used to hide the space temporarily (Figs 11-63a to 11-63d). Easily trimmed materials are suitable for the esthetic pontic because it should be shaped at the time of placement or during space closure

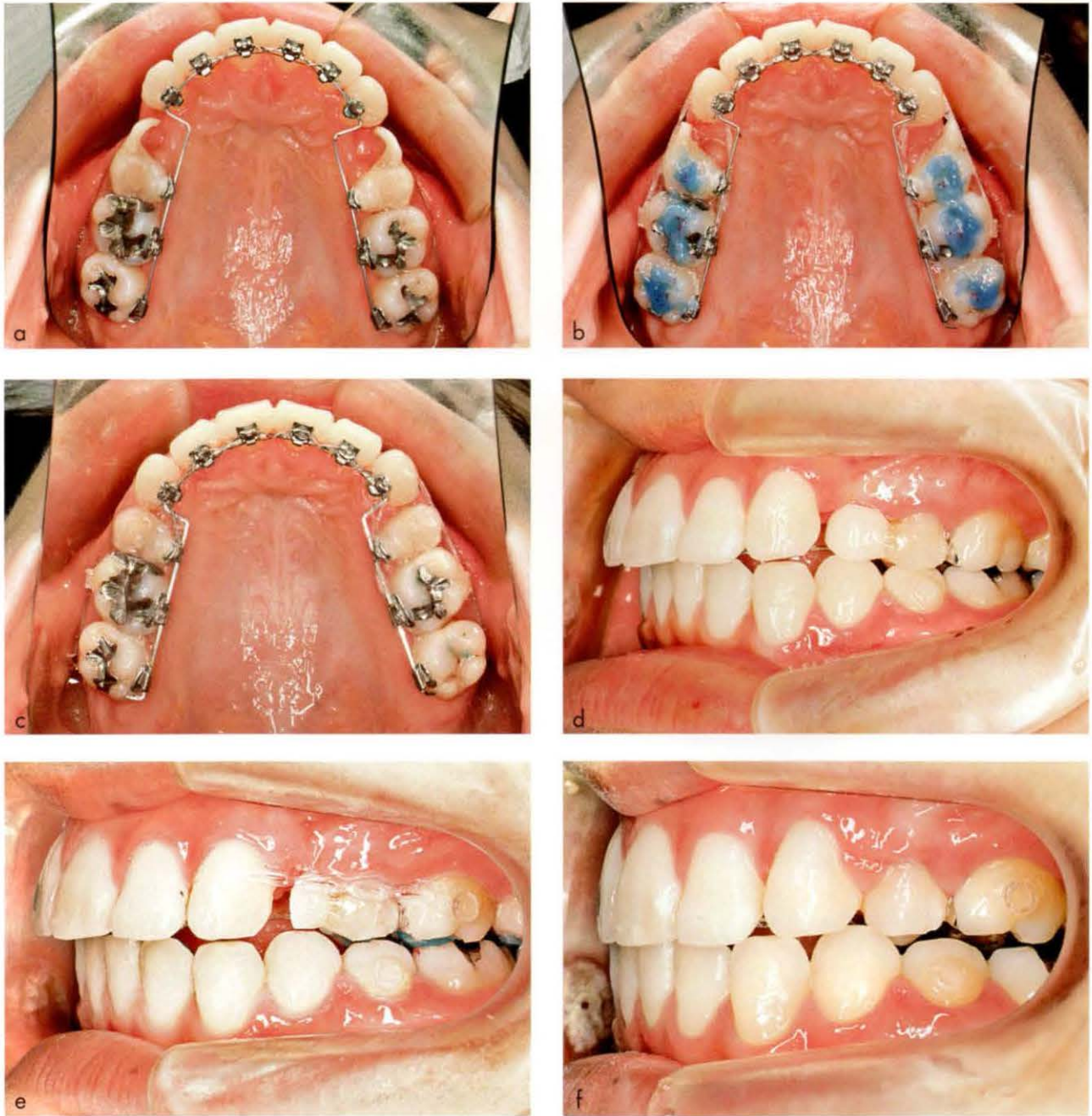


Figs 11-63a-d Esthetic pontic being prepared.

(Figs 11-64a to 11-64f). The esthetic pontic should be carefully adjusted at every visit because it may inhibit movement of adjacent teeth depending on how they move, or it may get embedded into the gingiva. There can be increased risk of gingivitis or caries, which may result because of accumulation of food debris in this area. Patients should be fully instructed of the importance of brushing to maintain good oral hygiene.

Closing the Space Produced between the Lateral Incisor and Canine after Partial Canine Retraction

After partial canine retraction, frequently a space is created between the lateral incisor and canine. On completion of leveling with a NiTi wire, the space is closed with a 0.016 or 0.0175 × 0.0175 TMA wire having a loop between the lateral incisor and canine. Usually, an L-loop is used in the maxillary arch where difference in height is likely to develop,



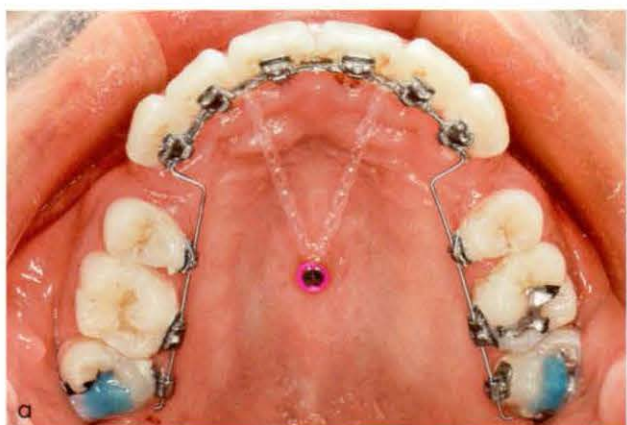
Figs 11-64a-f Adjusting the esthetic pontic during space closure.



Fig. 11-65 Closing the space produced between the lateral incisor and canine after partial canine retraction.



Fig. 11-66 Intruding the buccal cusp.



Figs 11-67a,b Glass ionomer cement applied to raise the bite.

and a vertical loop in the mandibular arch (Fig. 11-65). Ligation is continued beyond the extraction space to prevent the canine from relapsing.

Extrusion of the Opposite Tooth in the Extraction Space

Particularly after extraction of the maxillary first premolar or the mandibular second premolar, the buccal cusp of the opposite tooth may extrude into the extraction space and interfere with space closure. When this occurs, a temporary appliance is placed on the buccal surfaces of the opposing teeth to intrude the extruded buccal cusp because attempts to intrude the tooth from the lingual surface are far less efficient (Fig. 11-66).

Points to Note during Correction of the Canine Relationship

When a Class II canine relationship is being corrected to Class I, retraction of the maxillary canine may be obstructed by interference between the brackets on the maxillary and mandibular canines. In such a case, resin composite or glass ionomer cement is applied to the occlusal surfaces of the posterior segments temporarily for raising the bite (Figs 11-67a and 11-67b). If an orthodontic implant is used as an anchor, application of the resin composite or cement can be limited to the second molars. Otherwise, the resin composite is applied thoroughly to the posterior segment in order not to impair lateral occlusal function. As soon as the interference resolves, the resin composite is removed.

12 ILLUSTRATIVE STB EXTRACTION CASES

Case S.K. (1)

Chief Complaint, Examination Findings, and Diagnosis

A girl aged 17 years and 11 months complained of protruding front teeth and inability to bite. At the initial visit, the examination showed that she had an almost symmetrical face and in profile view she showed upper and lower lip protrusion. Intraorally, she had an anterior open bite with crowding and labial tipping of the maxillary and mandibular anterior teeth. The first molar relationship was an Angle Class I on both the right and left sides, with a 4 mm overjet and a -5 mm overbite. Both maxillary and mandibular dental midlines were almost coincident with the facial midline (Figs 12-1 and 12-2). Skeletal analysis revealed a slightly increased ANB angle and large gonial angle, with the mandible in

a retruded position and with clockwise rotation (Figs 12-3a to 12-3c).

The patient was a habitual mouth breather and also had a tongue thrust. Thus, a diagnosis of Angle Class I open bite with bimaxillary crowding was made.

Treatment Plan

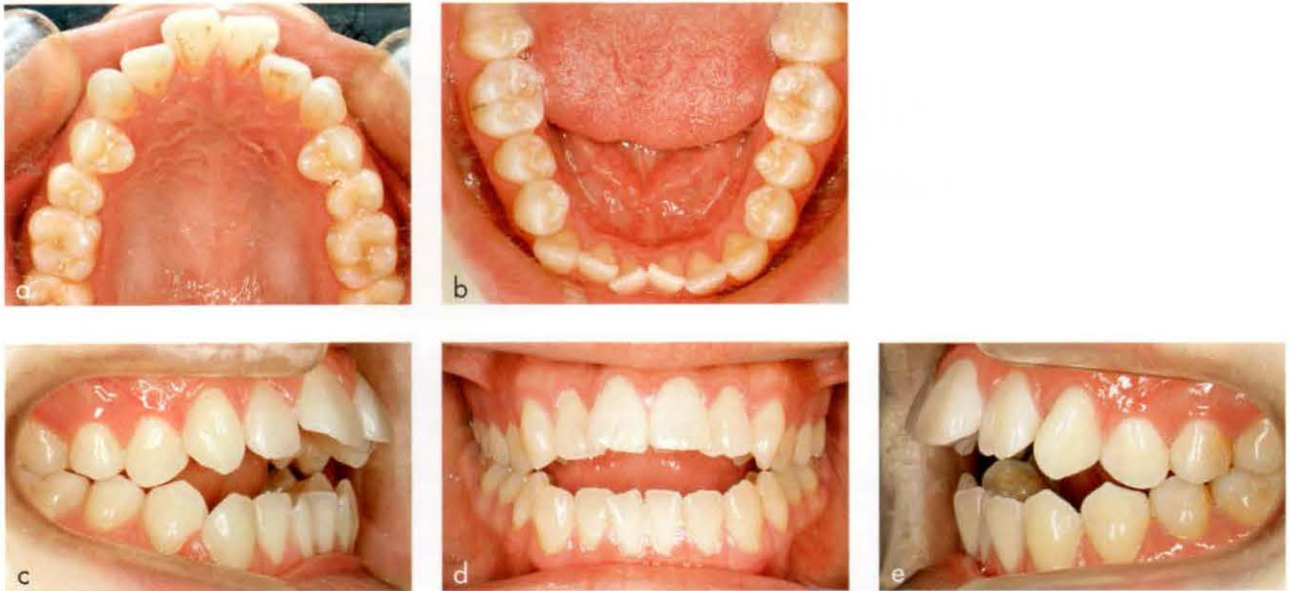
The treatment plan was to extract the maxillary and mandibular right and left first premolars and correct the axial inclination and alignment of the maxillary and mandibular anterior teeth as well as the open bite.

Treatment Details

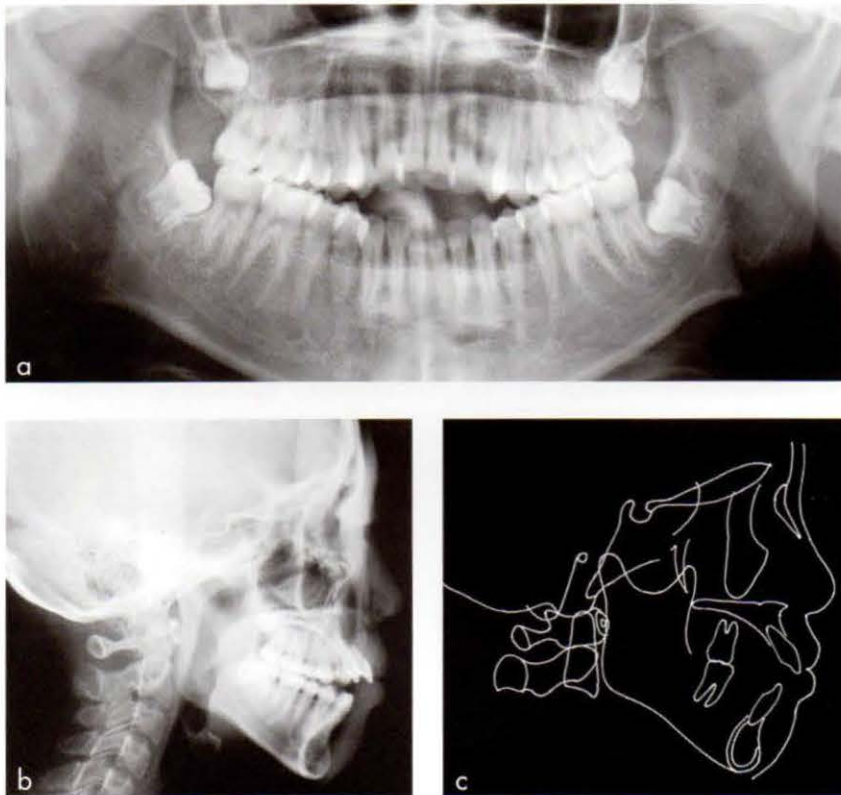
The STb lingual appliance (ORMCO, USA) was used as the orthodontic appliance. Following

Figs 12-1a,b Case S.K. (1): Pre-treatment extraoral photographs.





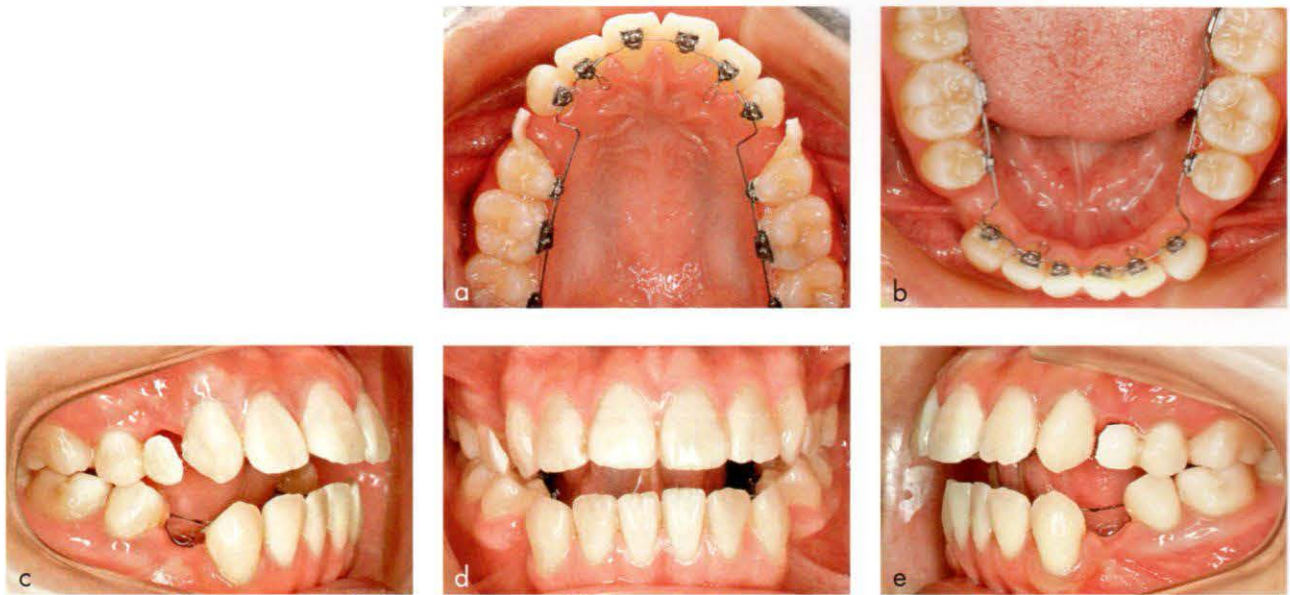
Figs 12-2a-e Case S.K. (1): Pretreatment intraoral photographs.



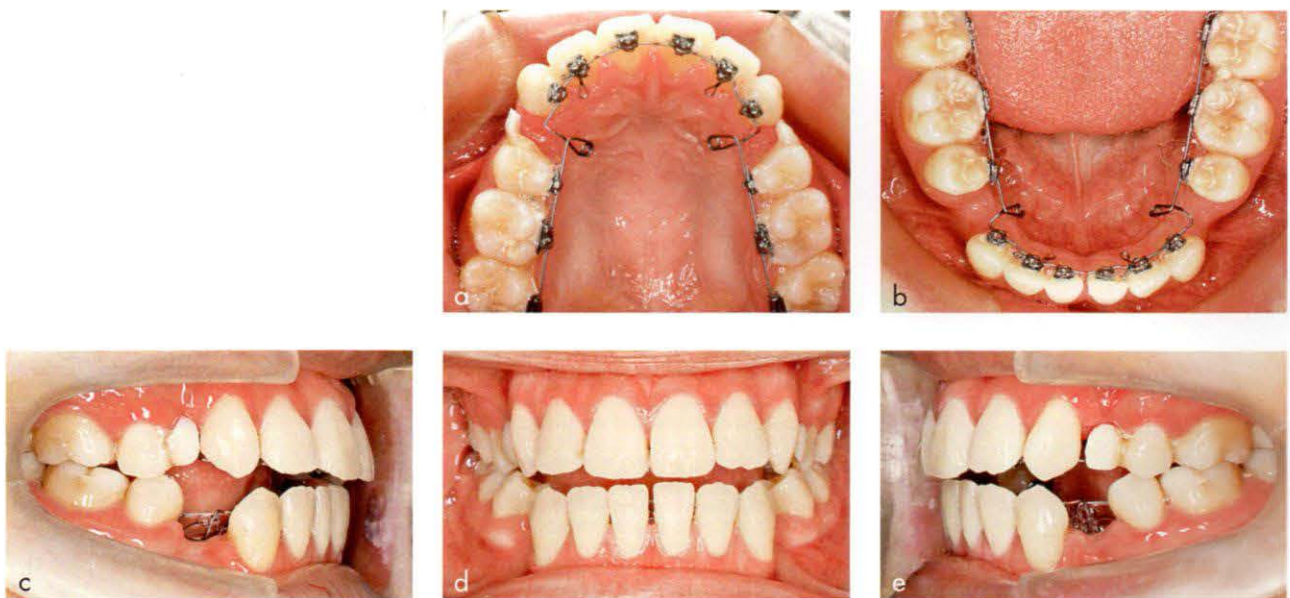
Figs 12-3a-c Case S.K. (1): Pretreatment radiographs.

extractions of the premolars, brackets were bonded indirectly to all teeth, and leveling started with 0.012 nickel titanium (NiTi) archwires. Two months after placement of the appliance, the first archwires

were replaced with 0.014 NiTi wires in both arches (Figs 12-4a to 12-4e). Up and down elastics were started between the maxillary and mandibular incisors.



Figs 12-4a-e Leveling with 0.014 NiTi archwires.

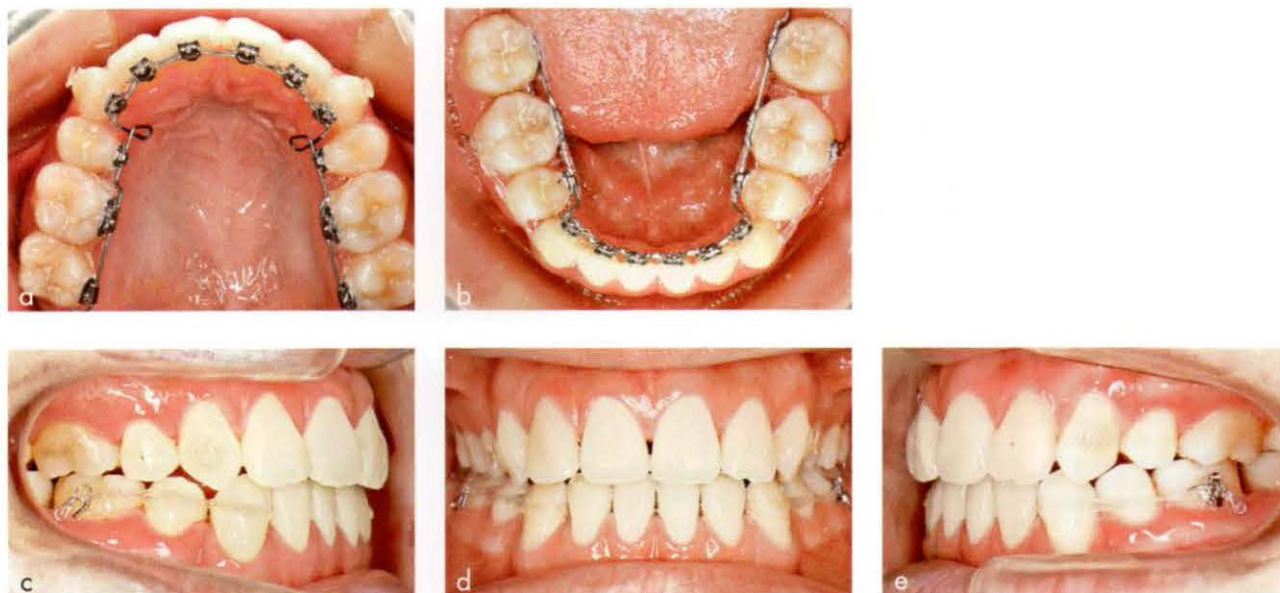


Figs 12-5a-e Space closure and overbite correction.

In the next stage the inclination of the labially tipped anterior teeth was corrected with closing loops built into 0.016 titanium molybdenum alloy (TMA) archwires, the open bite was closed, and space closure was commenced (Figs 12-5a to 12-5e). Up and down elastics were continued.

After overbite correction, en-masse retraction was started. For retraction, loop mechanics (0.0175 ×

0.0175 TMA archwires with closing loops) were used in the maxillary arch and sliding mechanics (0.016 × 0.022 stainless steel [SS] archwire) in the mandibular arch. Clear buttons were placed on the buccal surfaces of the maxillary right and left canines and the mandibular right and left first molars for Class II elastics (Figs 12-6a to 12-6e). The retraction time was about 6 months.



Figs 12-6a-e En-masse retraction.

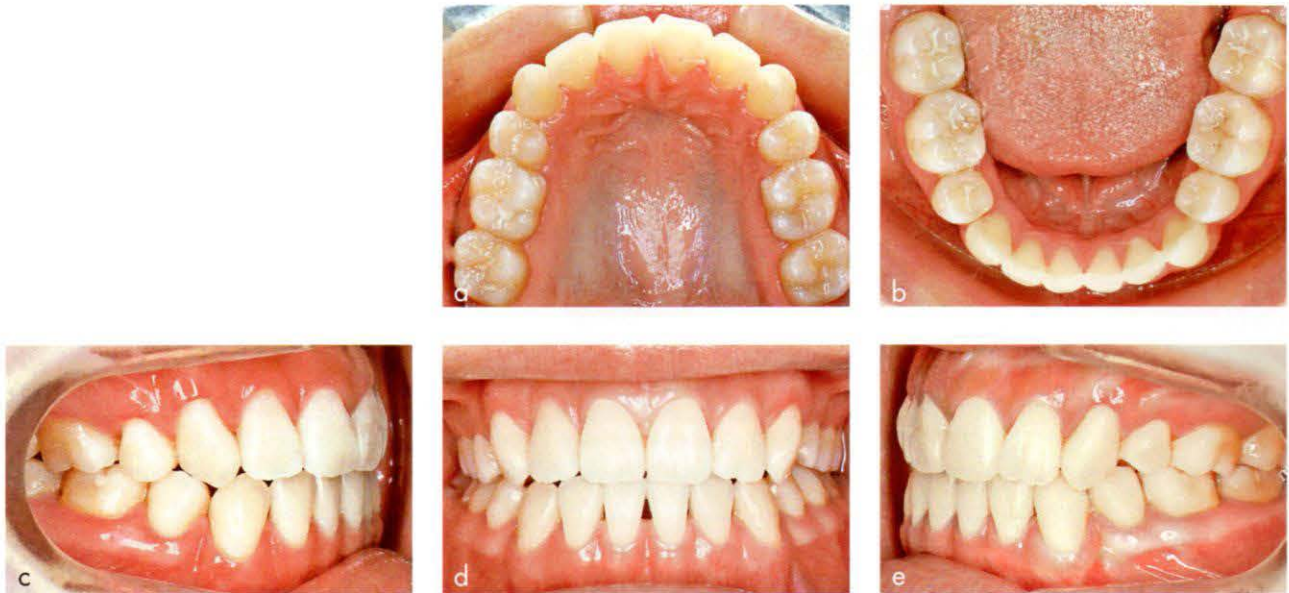


Figs 12-7a,b Case S.K. (1): Post-treatment extraoral photographs.

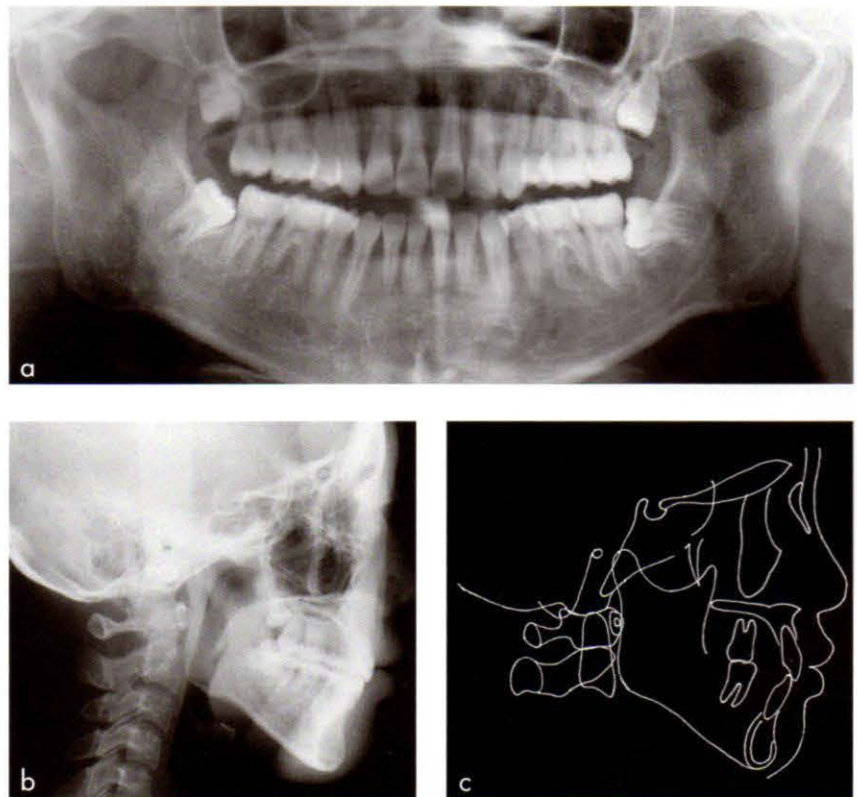
After space closure, detailing was done with 0.0175×0.0175 TMA archwires in both arches. The Class II elastics were continued. Diagonal elastics were also used between the maxillary right lateral incisor and the mandibular left lateral incisor to correct the midlines. The duration of detailing was about 6 months.

Post-treatment Analysis

On appliance removal, an Angle Class I molar relationship was achieved, the midlines were almost coincident, and a well-interdigitating occlusion was attained. Extraoral, intraoral, and cephalometric findings after appliance removal confirmed that the open bite of the anterior teeth was corrected and appropriate overjet and overbite were achieved. The profile was remarkably improved (Figs 12-7 to 12-9). The active treatment time was 20 months.



Figs 12-8a-e Case S.K. (1): Post-treatment intraoral photographs.



Figs 12-9a-c Case S.K. (1): Post-treatment radiographs.

Case Y.S. (1)

Chief Complaint, Examination Findings, and Diagnosis

A woman aged 21 years and 5 months complained of crowded upper anterior teeth. At the initial visit the patient had an almost symmetrical face and the profile examination revealed lower lip protrusion. Intraorally, she had severe crowding of the maxillary and mandibular anterior teeth with high maxillary right and left canines. The first molar relationship was Angle Class I both on the right and on the left sides, with a 3 mm overjet and a 2 mm overbite. The maxillary dental midline was almost coincident with the facial midline while the mandibular midline was shifted 0.5 mm to the right. In the skeletal analysis, the lateral cephalogram showed almost normal SNA and SNB angles, and the maxillomandibular anteroposterior relationship was normal. The face was almost symmetrical.

Thus, a diagnosis of Angle Class I malocclusion with crowding of the maxillary and mandibular teeth was made (Figs 12-10 to 12-12).

Treatment Plan

The treatment plan was to extract the maxillary and mandibular right and left first premolars for correction of crowding. Since severity of crowding

of the maxillary and mandibular anterior teeth did not allow immediate placement of brackets, it was decided to correct the crowding first with a lingual arch.

Treatment Details

The STb lingual appliance (STb, from ORMCO, USA) was used as orthodontic appliance. The maxillary and mandibular right and left first molars were banded and lingual arches placed. Canine retraction was initiated with cleats bonded to the lingual surfaces of the maxillary and mandibular right and left canines (Figs 12-13a to 12-13e). At the same time, the maxillary right and left lateral incisors were pushed labially with springs welded on the lingual arch.

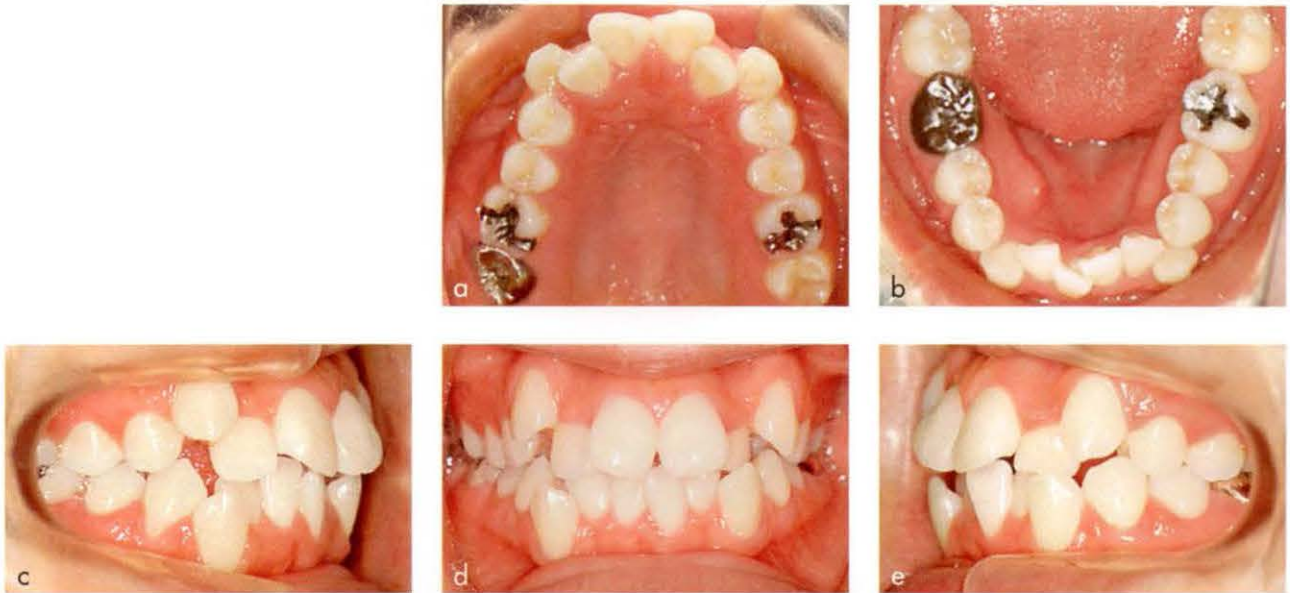
In about 3 months, the anterior crowding was gradually resolved. The maxillary and mandibular lingual arches were removed, and brackets bonded with the indirect method. In both arches initial 0.012 NiTi archwires were used and leveling initiated.

Next, 0.016 × 0.016 NiTi archwires were used in both arches, followed by 0.0175 × 0.0175 TMA archwires, for simultaneous torque establishment (Figs 12-14a to 12-14e).

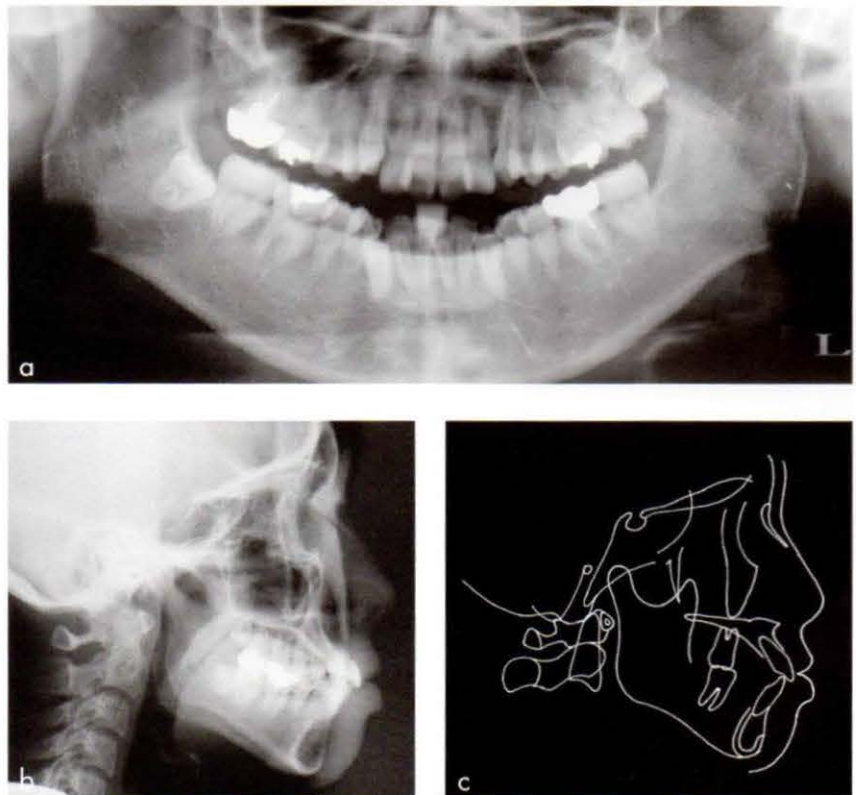
When leveling and torque establishment were completed, en-masse retraction was initiated in the maxillary arch with loop mechanics (0.017 × 0.025 TMA archwires with T-loops) and in the



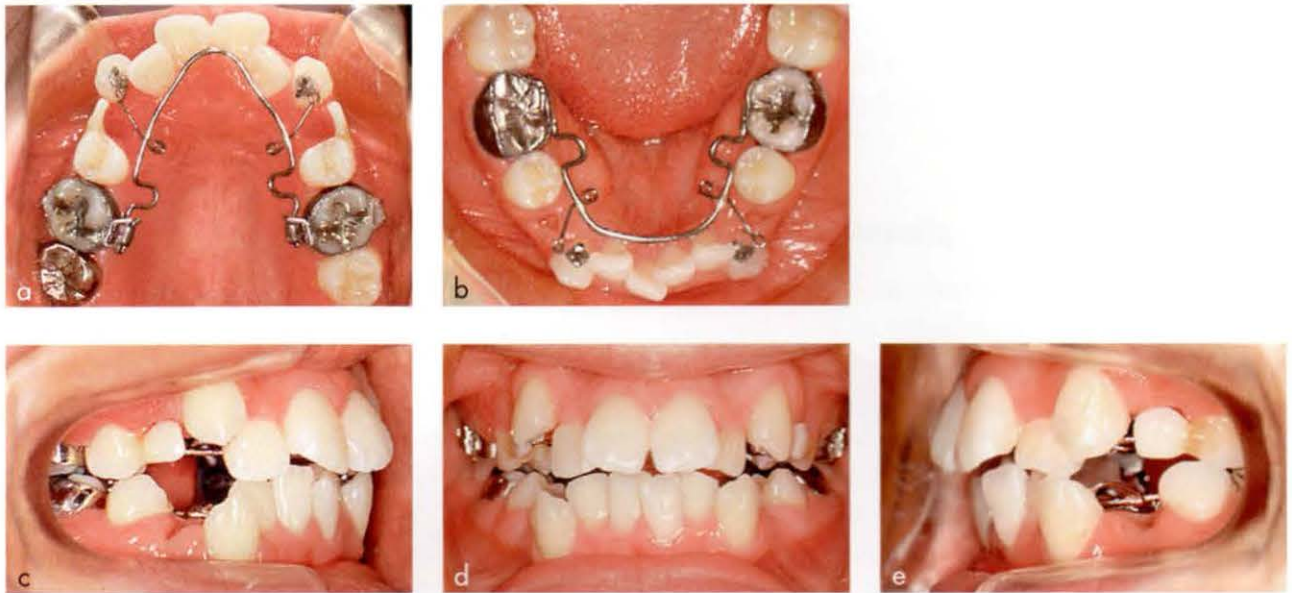
Figs 12-10a,b Case Y.S. (1): Pre-treatment extraoral photographs.



Figs 12-11a-e Case Y.S. (1): Pretreatment intraoral photographs.



Figs 12-12a-c Case Y.S. (1): Pretreatment radiographs.



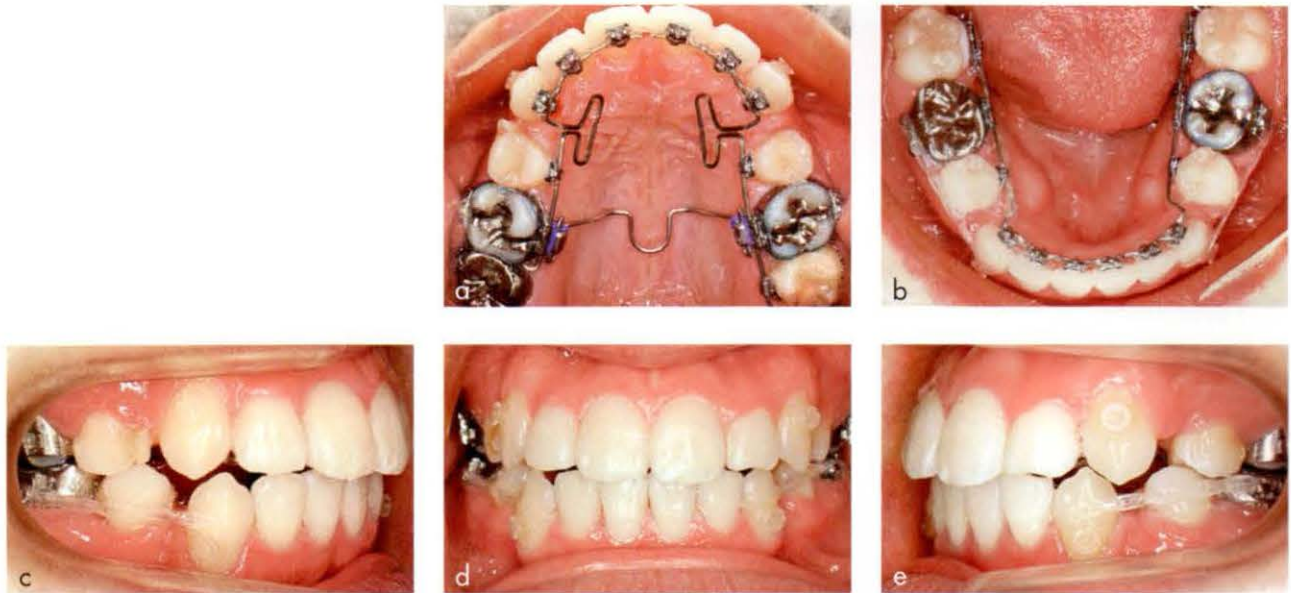
Figs 12-13a-e Decrowding with lingual arches and cleats.



Figs 12-14a-e Establishment of torque.

mandibular arch with sliding mechanics (0.016 × 0.022 SS wire). A transpalatal arch (TPA) was placed on the maxillary right and left first molars for reinforcement of anchorage (Figs 12-15a to 12-15e). Class II elastics were used on the clear buttons placed on the buccal surfaces of the maxillary right and left canines and the mandibular right and

left first molars. The TPA was used for 5 months. After retraction was complete, the TPA was removed. Detailing was initiated with a 0.016 TMA wire in the maxillary arch and a 0.0175 × 0.0175 TMA wire in the mandibular arch. Up and down elastics were started on the maxillary and mandibular canines. Detailing required 3 months.



Figs 12-15a-e En-masse retraction.

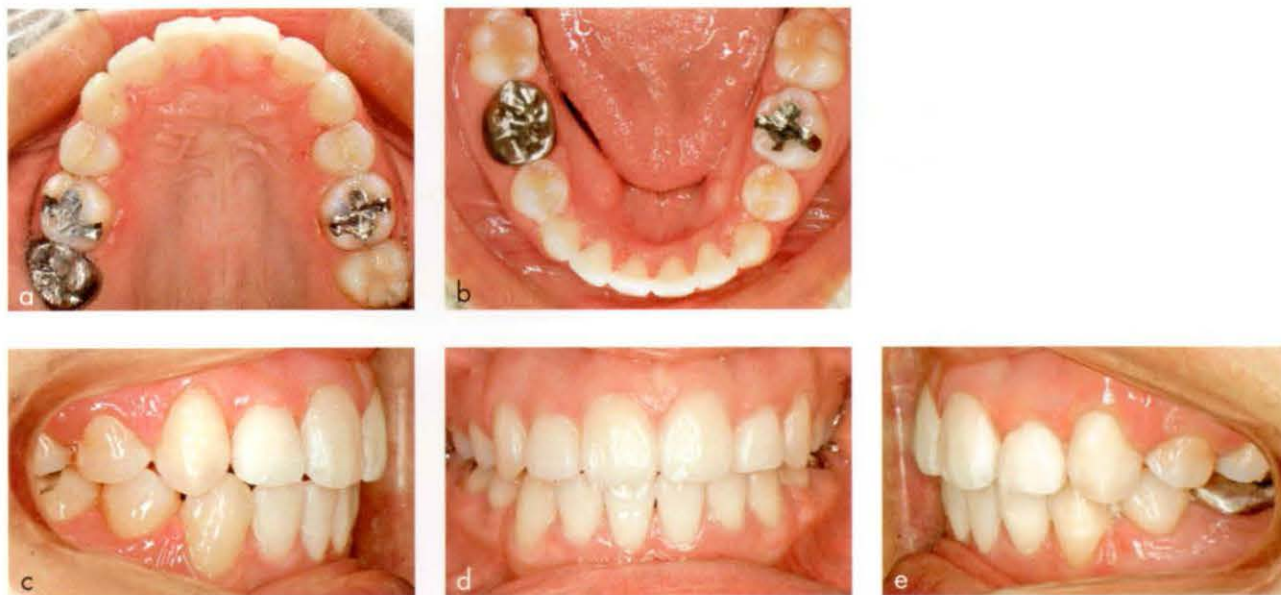


Figs 12-16a,b Case Y.S. (1): Post-treatment extraoral photographs.

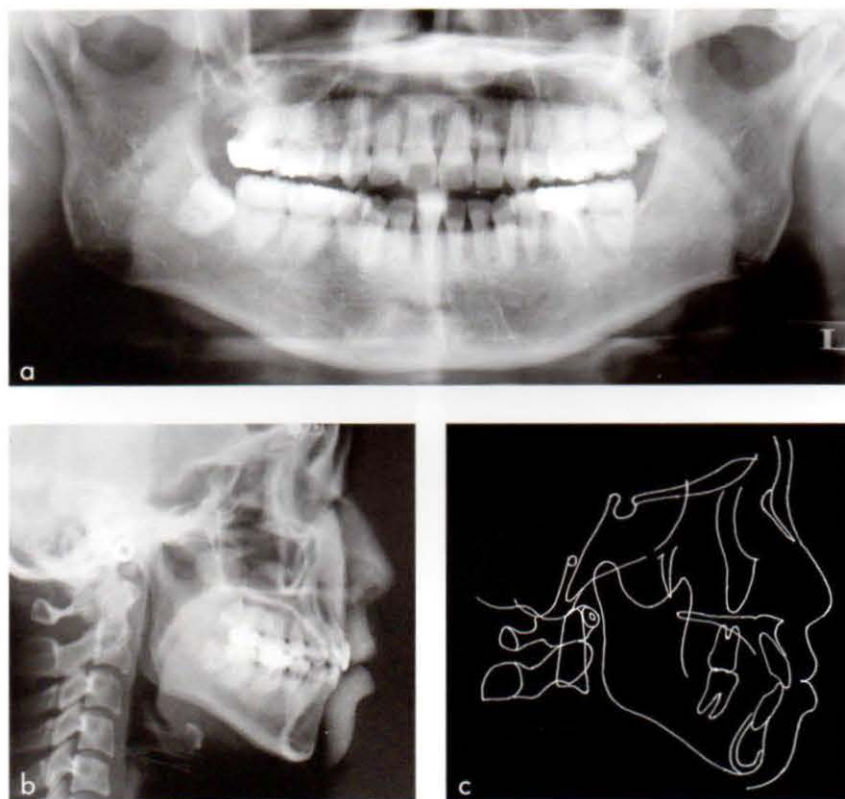
Post-treatment Analysis

An Angle Class I molar relationship with coincident maxillary and mandibular midlines and a well-interdigitating occlusion was obtained. The extraoral and intraoral findings after appliance removal confirmed that appropriate overjet and overbite

were achieved, the crowding was corrected, and the profile was improved (Figs 12-16 to 12-18). The active treatment time was 17 months.



Figs 12-17a-e Case Y.S. (1): Post-treatment intraoral photographs.



Figs 12-18a-c Case Y.S. (1): Post-treatment radiographs.

CASE Y.S. (2)

Chief Complaint, Examination Findings, and Diagnosis

A woman aged 23 years and 8 months complained of protruding front teeth. At the initial visit the patient had an almost symmetrical face and profile examination revealed lower lip protrusion. Intraorally, she had moderate crowding and labial tipping of the maxillary and mandibular anterior teeth. The first molar relationship was Angle Class I both on the right and on the left sides, with a 5 mm overjet and a 2 mm overbite. The maxillary arch midline was coincident with the facial midline while the mandibular arch midline was shifted 0.5 mm to the left. In the skeletal analysis, the lateral cephalogram showed almost normal SNA and SNB angles, and the maxillomandibular anteroposterior relationship was normal. The face was almost symmetrical.

Thus, a diagnosis of Angle Class I bimaxillary protrusion with crowding of the maxillary and mandibular anterior teeth was made (Figs 12-19 to 12-21).

Treatment Plan

The treatment plan was to extract the maxillary and mandibular right and left first premolars for correction of crowding and axial inclination of the anteriors,

and use miniscrew implants (O.S.A.S., DEWIMED Medizintechnik GmbH, Germany) in the maxillary posterior segments for maximum anchorage.

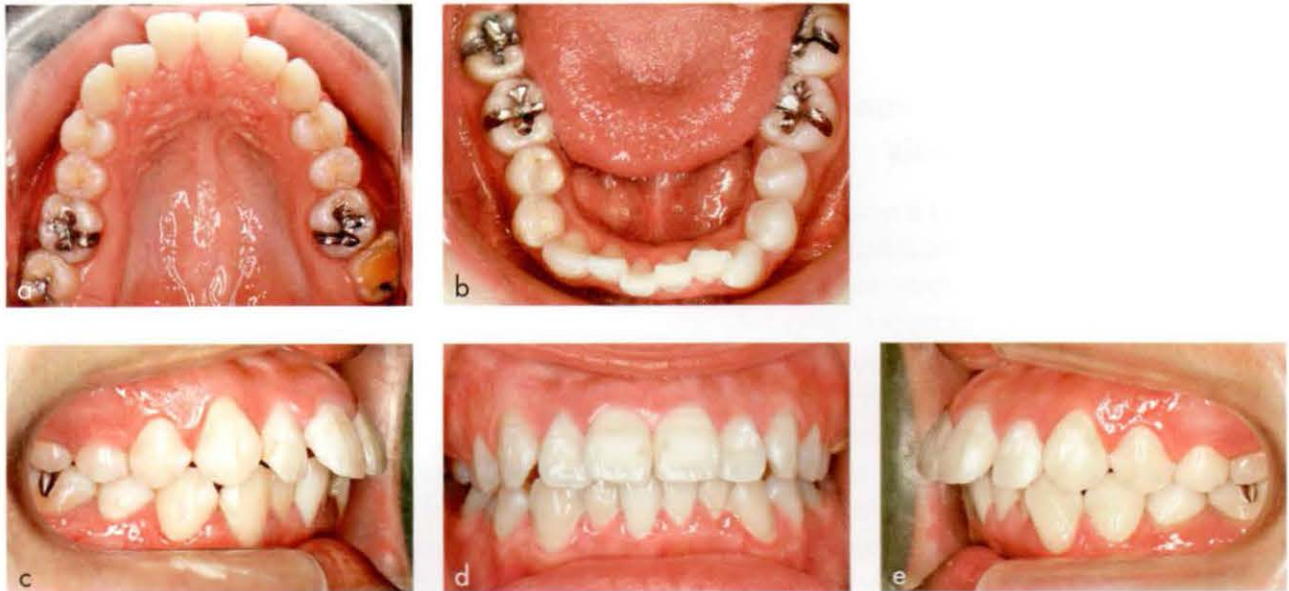
Treatment Details

The STb lingual appliance (STb, from ORMCO, USA) was used as the orthodontic appliance. Following extraction of the four first premolars, the maxillary first molars and mandibular second molars were banded, and brackets were indirectly bonded to the remaining teeth. The maxillary and mandibular second molars did not allow appliance placement because of low crown height of their lingual surfaces, so the appliance was placed on their buccal surfaces to achieve control. In both arches initial 0.010 NiTi archwires were used to start leveling. To correct the mesial rotation of the mandibular left second premolar, power chains were used on clear buttons attached to the buccal surfaces of the first molar and the second premolar for control from the buccal side, and from the bracket of the left canine to the bracket of the second premolar for control from the lingual side.

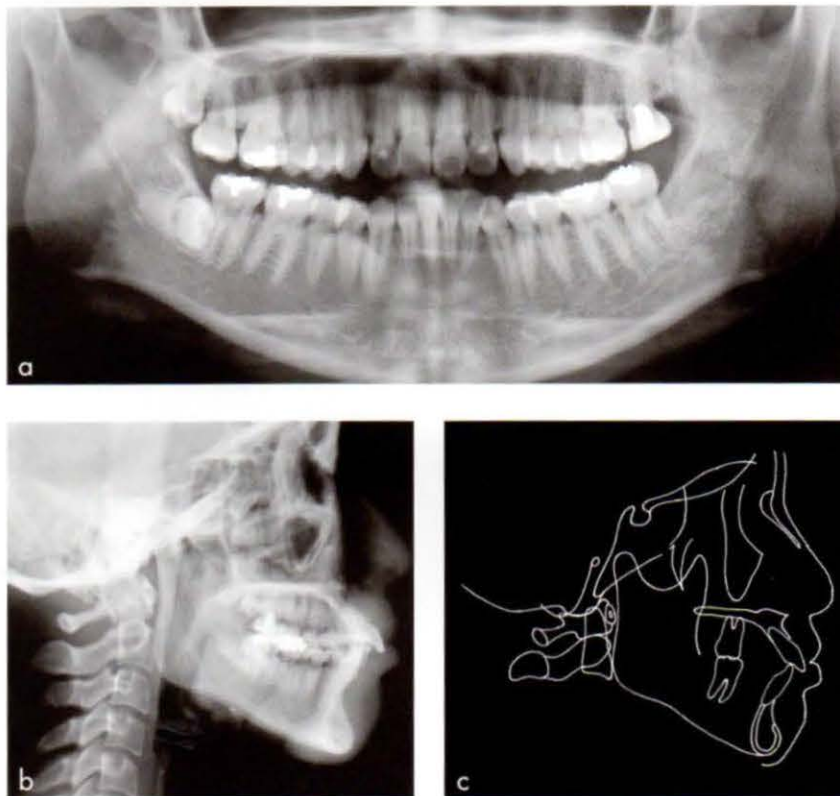
Next, the wire in the maxillary arch was replaced with a 0.012 NiTi wire. On the buccal side of the mandibular left first and second molars, a 0.016 × 0.016 NiTi sectional wire was inserted. Correction of rotation of the mandibular left second premolar was continued (Figs 12-22a to 12-22e).



Figs 12-19a,b Case Y.S. (2): Pre-treatment extraoral photographs.



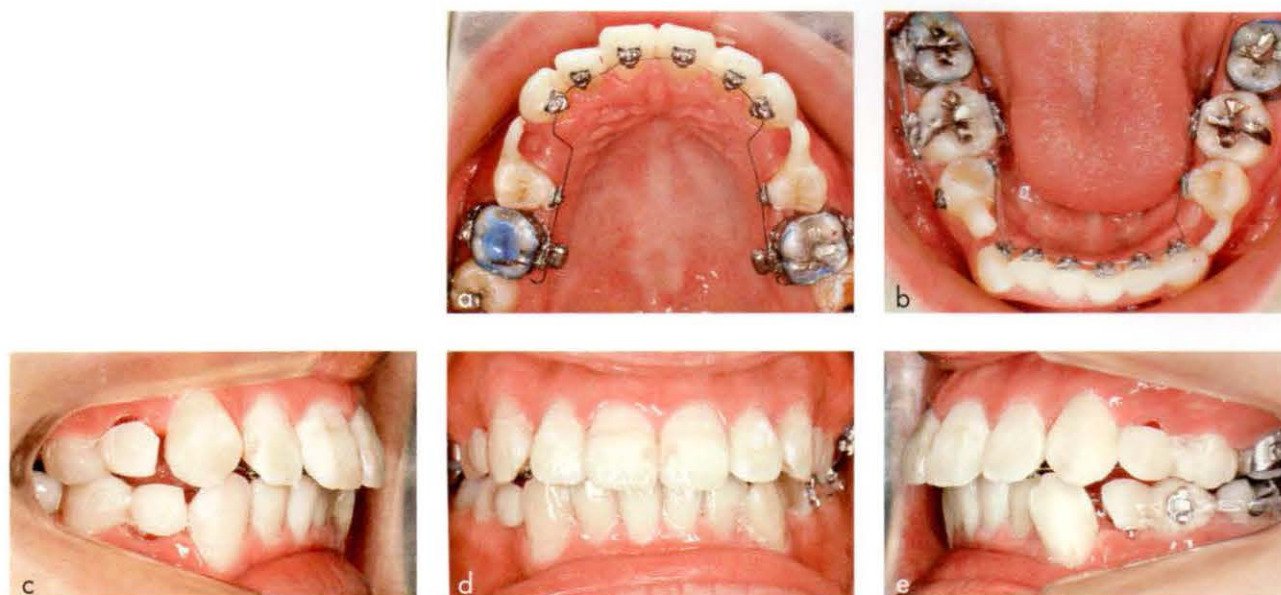
Figs 12-20a-e Case Y.S. (2): Pretreatment intraoral photographs.



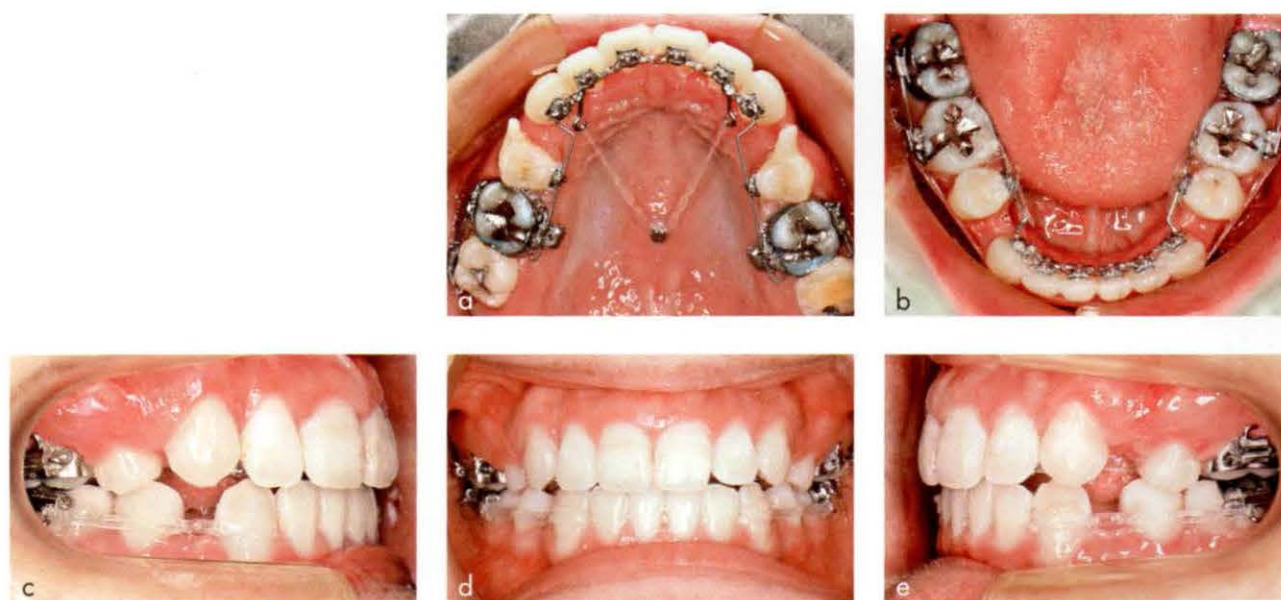
Figs 12-21a-c Case Y.S. (2): Pretreatment radiographs.

Crowding and rotation were corrected, and leveling was finished in 7 months. Then torque establishment was initiated in both arches with 0.0175 × 0.0175 TMA wires. After torque establishment

was completed, miniscrew implants were placed in the midpalatal suture for maximum anchorage in the maxillary arch. A 0.017 × 0.025 Wilcock wire (A.J. Wilcock, Australia) was used. Power



Figs 12-22a-e Leveling and derotation of the left mandibular second premolar.

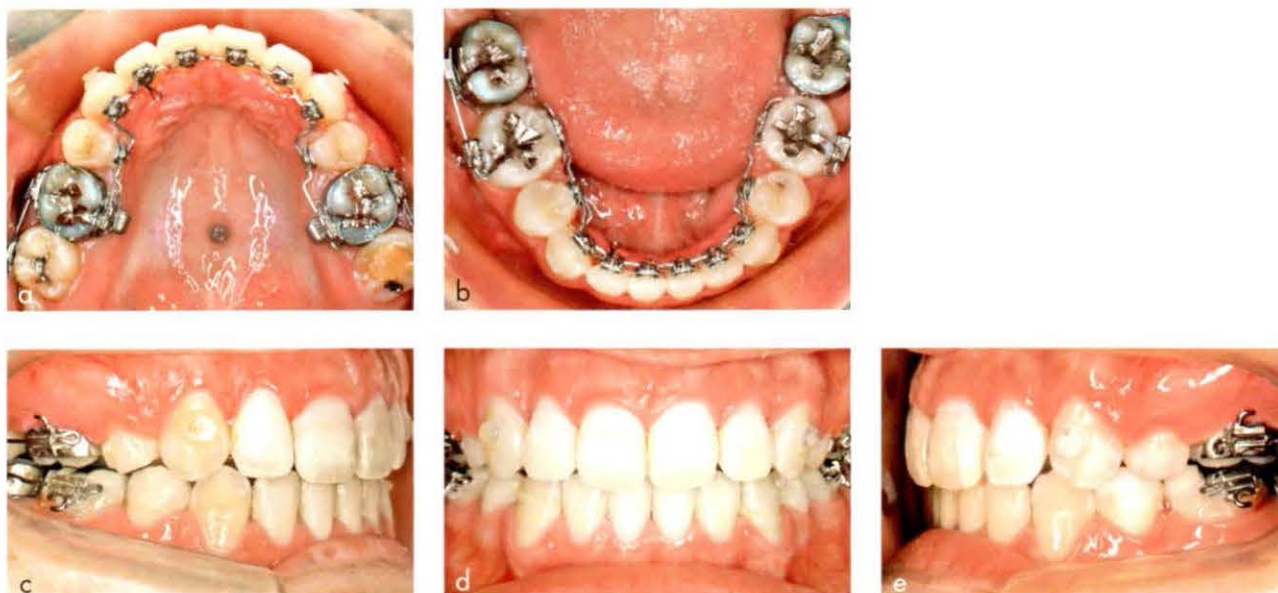


Figs 12-23a-e En-masse retraction.

chains were placed from the hooks attached to the archwire between the lateral incisor and canine to the miniscrew implant for en-masse retraction with sliding mechanics. En-masse retraction in the mandibular arch was started with sliding mechanics (0.016 × 0.022 SS wire) and 0.016 × 0.022 NiTi sectional wires were used on the buccal sides of the first and second molars in the maxillary and

mandibular arches to maintain control of the second molars (Figs 12-23a to 12-23e). Duration of retraction was approximately 8 months.

Following space closure in both arches, detailing in the maxillary arch was initiated with a 0.0175 × 0.0175 TMA wire (Figs 12-24a to 12-24e). Class II elastics were started between the mandibular first molars and clear buttons placed on the buccal sur-



Figs 12-24a-e Detailing.

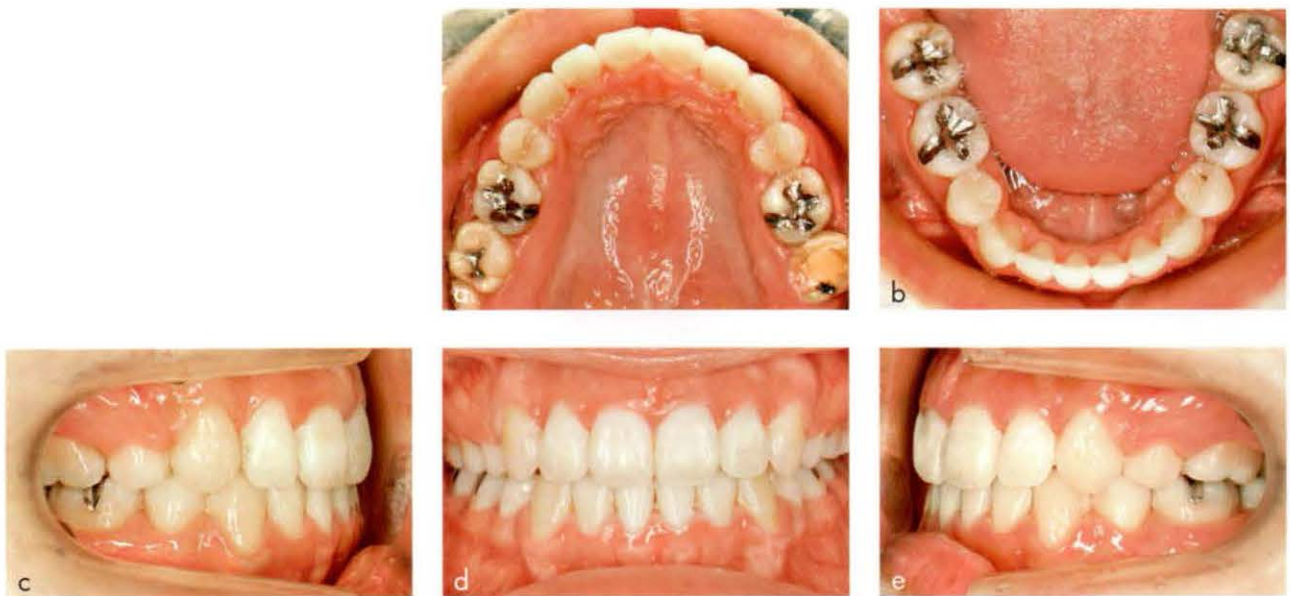


Figs 12-25a,b Case Y.S. (2): Post-treatment extraoral photographs.

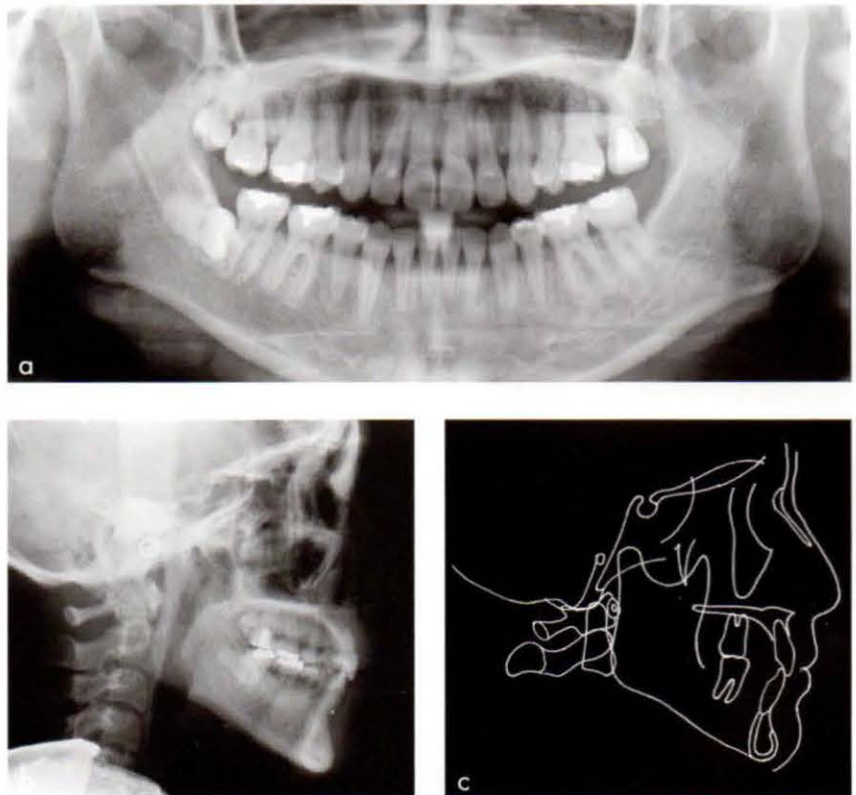
face of the maxillary canines on both right and left sides. Diagonal elastics were also used between the maxillary right lateral incisor and the mandibular left lateral incisor to correct the midlines. Detailing was achieved in 5 months.

Post-treatment Analysis

An Angle Class I molar relationship with a well-interdigitating occlusion was achieved with coincident midlines. The extraoral and intraoral findings after appliance removal confirmed that appropriate overjet and overbite were achieved, the crowding and the axial inclinations of the anterior were corrected, and the profile was remarkably improved (Figs 12-25 to 12-27). The active treatment time was 20 months.



Figs 12-26a-e Case Y.S. (2): Post-treatment intraoral photographs.



Figs 12-27a-c Case Y.S. (2): Post-treatment radiographs.

Case T.K.

Chief Complaint, Examination Findings, and Diagnosis

A woman aged 32 years and 6 months complained of prominent front teeth. At the initial visit the patient had an almost symmetrical face and profile examination revealed lip protrusion. Intraorally, she had mild crowding of the maxillary and mandibular anterior teeth and pronounced labial tipping of the maxillary anteriors. The first molar relationship was a mild Angle Class II both on the right and on the left sides, with a 4 mm overjet and a 1 mm overbite, and the maxillary and mandibular dental midlines were almost coincident with the facial midline. In the skeletal analysis, the lateral cephalogram revealed large ANB and gonial angles, and the mandible was in a retruded position and rotated posteroinferiorly (clockwise). The face was almost symmetrical.

Thus, a diagnosis of Angle Class II malocclusion with maxillary protrusion and crowding of the maxillary and mandibular anteriors and labial tipping of the maxillary anteriors was made (Figs 12-28 to 12-30).

Treatment Plan

The treatment plan was to extract the maxillary and mandibular right and left first premolars for correc-

tion of overjet and crowding, and use miniscrew implants (Abso anchor, Dentos, Korea) for maximum anchorage in the maxillary posterior segments.

Treatment Details

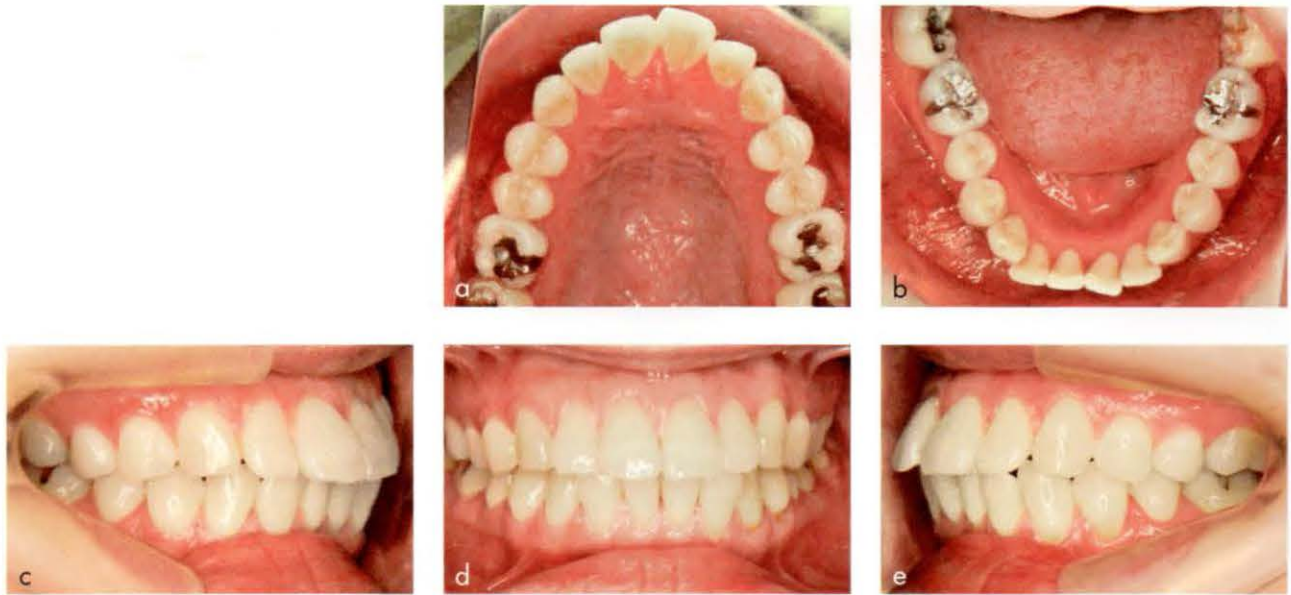
The STb Lingual appliance (STb, from ORMCO, USA) was used as the orthodontic appliance. Following extraction of the maxillary right and left first premolars, the first molars were banded, and brackets bonded indirectly to all the remaining teeth. Leveling was started with a 0.012 NiTi wire in the maxillary arch and a 0.014 NiTi in the mandibular arch, and partial retraction of the canines was also commenced.

Two months after appliance placement, 0.016 × 0.016 NiTi wires were placed in both arches for torque establishment (Figs 12-31a to 12-31e). In the mandibular arch, power chains were used between the right and left canines to close the spaces produced by partial retraction; the canines and the second premolars were ligated to prevent posterior space opening as a reaction to the anterior space closure. Torque establishment was continued with 0.0175 × 0.0175 TMA wires in both arches.

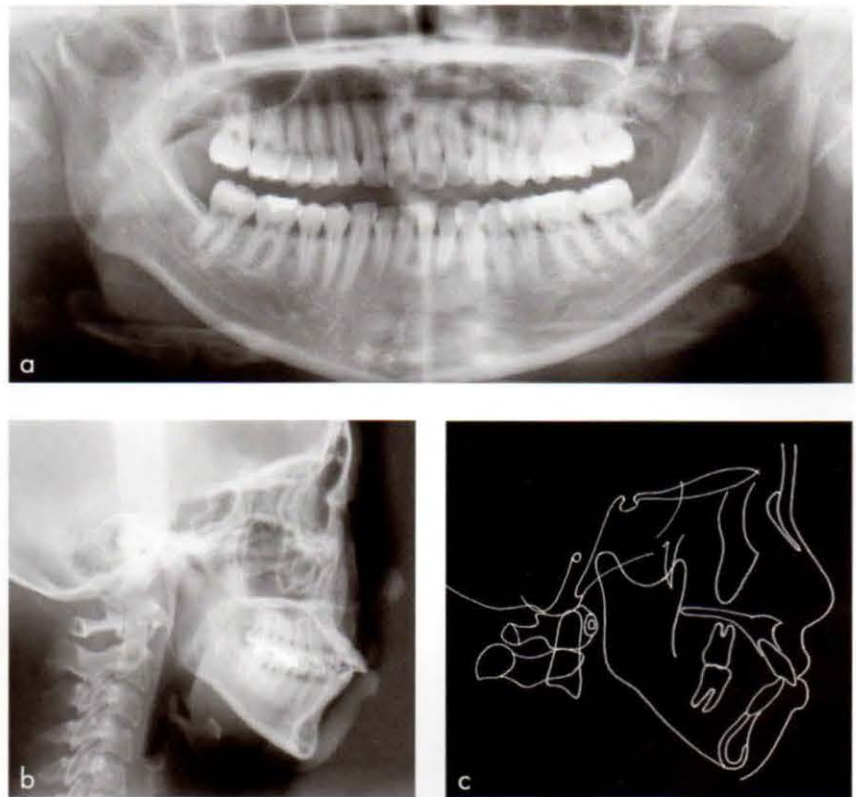
After torque establishment, in the maxillary arch, miniscrew implants were placed in the lingual alveolar bone between the second premolars and the first molars for maximum anchorage. En-masse retraction in the maxillary arch was initiated with



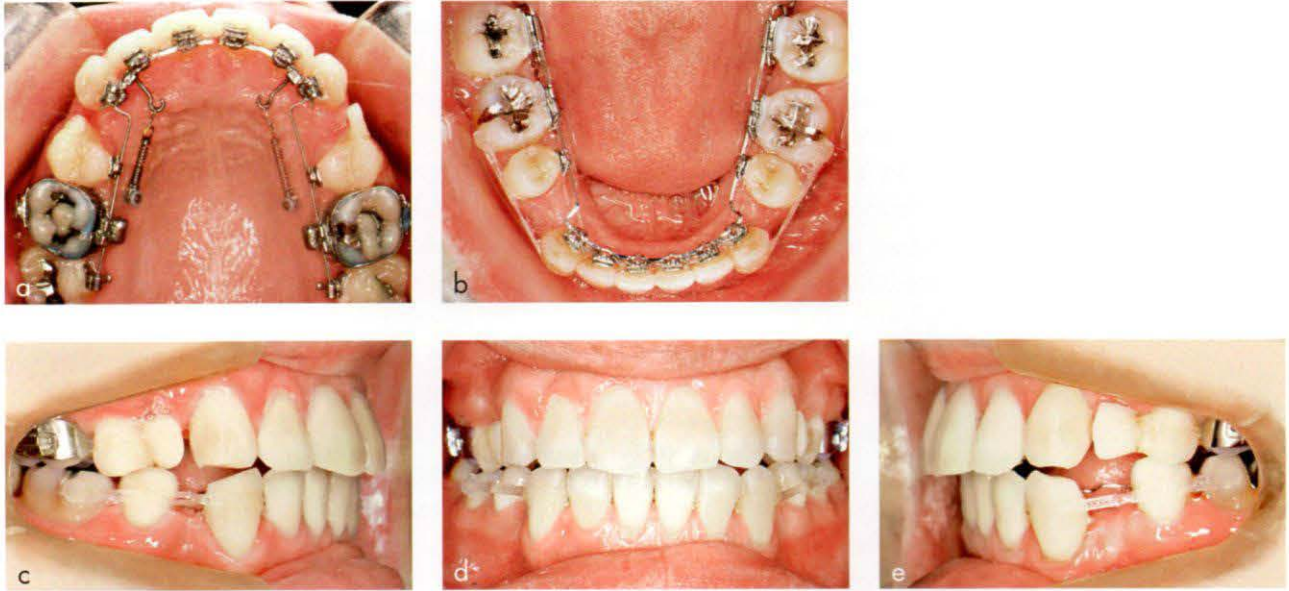
Figs 12-28a,b Case T.K.: Pre-treatment extraoral photographs.



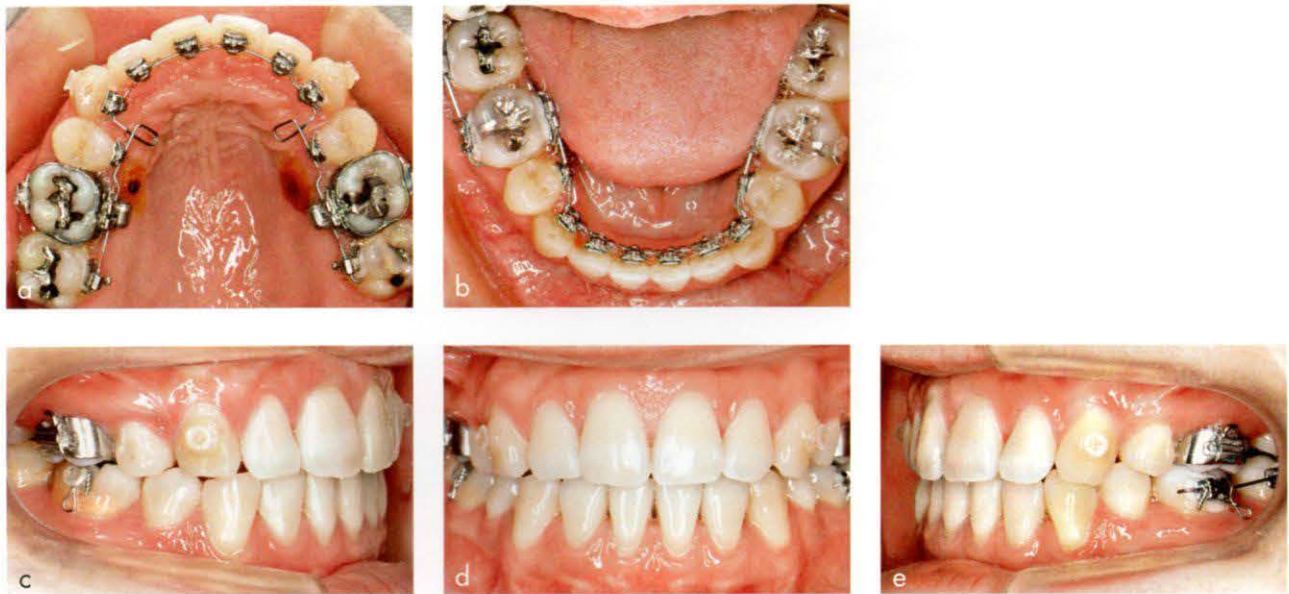
Figs 12-29a-e Case T.K.: Pretreatment intraoral photographs.



Figs 12-30a-c Case T.K.: Pretreatment radiographs.



Figs 12-32a-e En-masse retraction.



Figs 12-33a-e Detailing.

sliding mechanics using a 0.017 × 0.025 Wilcock wire (A.J. Wilcock) and closed coils between the miniscrew implants and the hooks attached to the archwire between the lateral incisors and the canines. En-masse retraction in the mandibular arch was initiated with sliding mechanics (0.016 × 0.022 SS) (Figs 12-32a to 12-32e). The retraction time was 10 months.

After space closure, the miniscrew implants were removed. Detailing was initiated with a 0.016 TMA archwire in the maxillary arch and a 0.0175 × 0.0175 TMA in the mandibular arch. During this period, Class II elastics were started between the mandibular first molars and clear buttons placed on the buccal surfaces of the maxillary canines. It took about 6 months for detailing (Figs 12-33a to 12-33e).



Figs 12-34a,b Case T.K.: Post-treatment extraoral photographs.

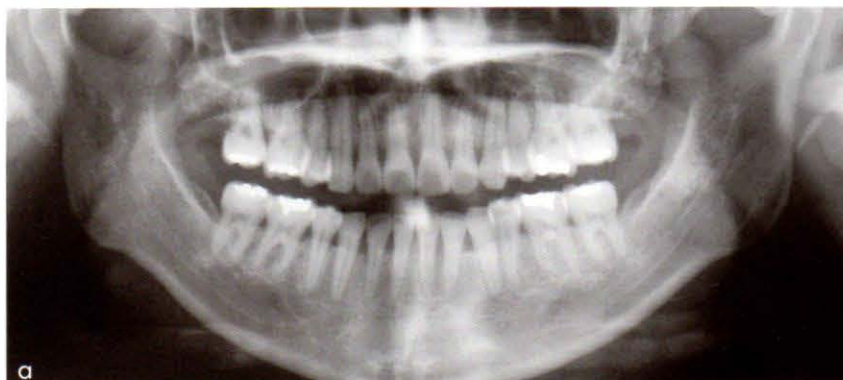


Figs 12-35a-e Case T.K.: Post-treatment intraoral photographs.

Post-treatment Analysis

An Angle Class I molar relationship with almost coincident midlines and a well-interdigitating occlusion was attained. The extraoral and intraoral findings after appliance removal confirmed that appropriate overjet and overbite were achieved, crowding and the maxillary anterior axial inclina-

tions were corrected, and the profile was improved (Figs 12-34 to 12-36). The active treatment time was 24 months.



Figs 12-36a-c Case T.K.: Post-treatment radiographs.

Case S.K. (2)

Chief Complaint, Examination Findings, and Diagnosis

A woman aged 25 years and 11 months complained of irregular teeth and deviated chin point. At the initial visit, the patient showed facial asymmetry with the mandible shifted toward the left and altered shape of the lips. The profile examination revealed slight lip protrusion. Intraorally, in the maxillary arch, the left first premolar was tipped distally as the second premolar was missing, and there were spaces between the lateral incisor and canine and between the canine and first premolar on the same side. There were very mild crowding and spaces in the mandibular arch. The maxillary and mandibular left lateral incisors and canines were in crossbite. The right first molar relationship was Angle Class III and on the left side the molar relationship was Angle Class I, with a 2 mm overjet and a 2 mm overbite. The maxillary dental midline was coincident with the facial midline while the mandibular midline was shifted 3 mm to the left. On skeletal analysis, the lateral cephalogram showed an ANB angle of -2 degrees, with the mandible positioned slightly forward and the face showed a leftward shift of the mandible.

Thus, a diagnosis of skeletal Class I malocclusion with a Class III tendency, mandibular protrusion, and

shift toward the left with a missing maxillary left second premolar was made (Figs 12-37 to 12-39).

Treatment Plan

A combined orthodontic and surgical treatment approach without extraction was chosen to correct the leftward shift of the mandible. The maxillary left second premolar site, where the tooth was missing, was to be restored following regaining of the space with orthodontic treatment.

Treatment Details

The STb lingual appliance (ORMCO, USA) was used as the orthodontic appliance. The maxillary and mandibular right and left first and second molars were banded, and brackets were indirectly bonded on the remaining teeth. In both arches, initial 0.012 NiTi archwires were used for leveling.

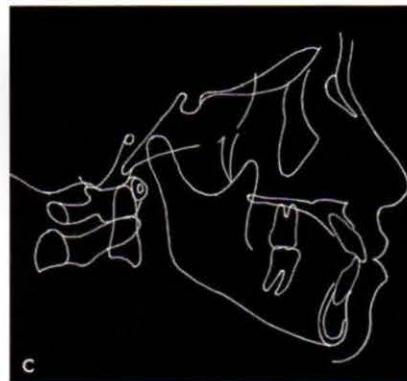
Next, the wire in the maxillary arch was replaced with a 0.016 NiTi wire, and power chains were used to close the spaces between the left and right canines. To regain and maintain space for replacement of the left second premolar, open coil springs were used between the first premolar and the first molar. The size of the wire in the mandibular arch was kept unchanged, and power chains were used from the right first premolar to the left canine for correction of mesial rotation of the right first premolar



Figs 12-37a,b Case S.K. (2): Pre-treatment extraoral photographs.



Figs 12-38a-e Case S.K. (2): Pretreatment intraoral photographs.

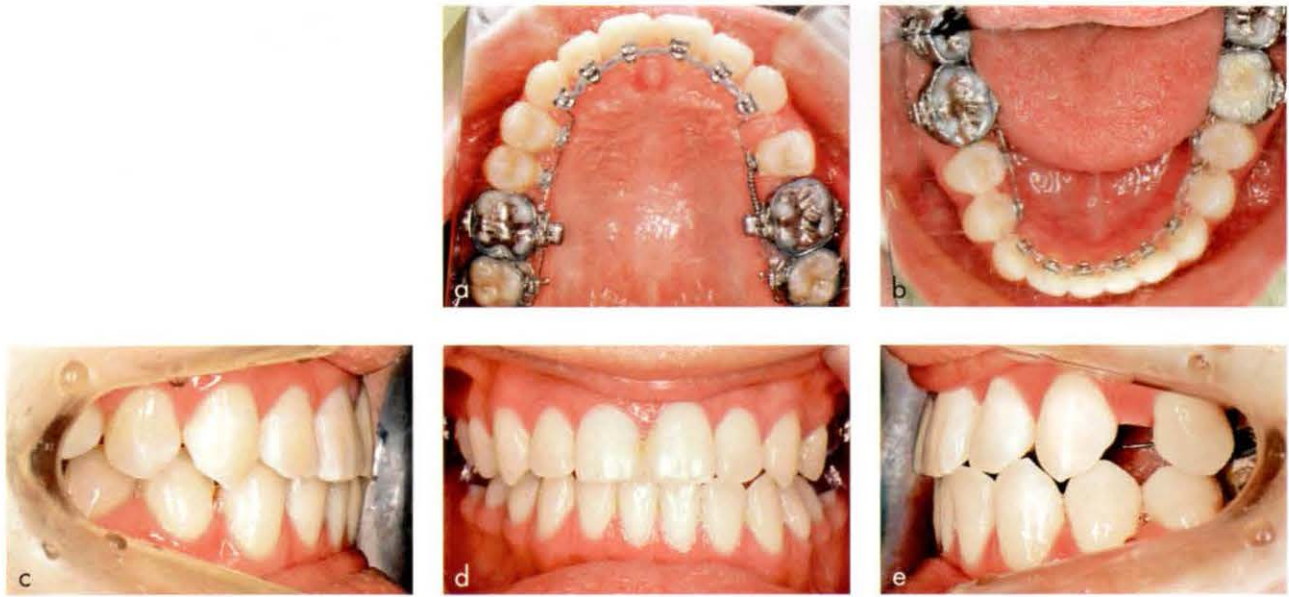


Figs 12-39a-c Case S.K. (2): Pretreatment radiographs.

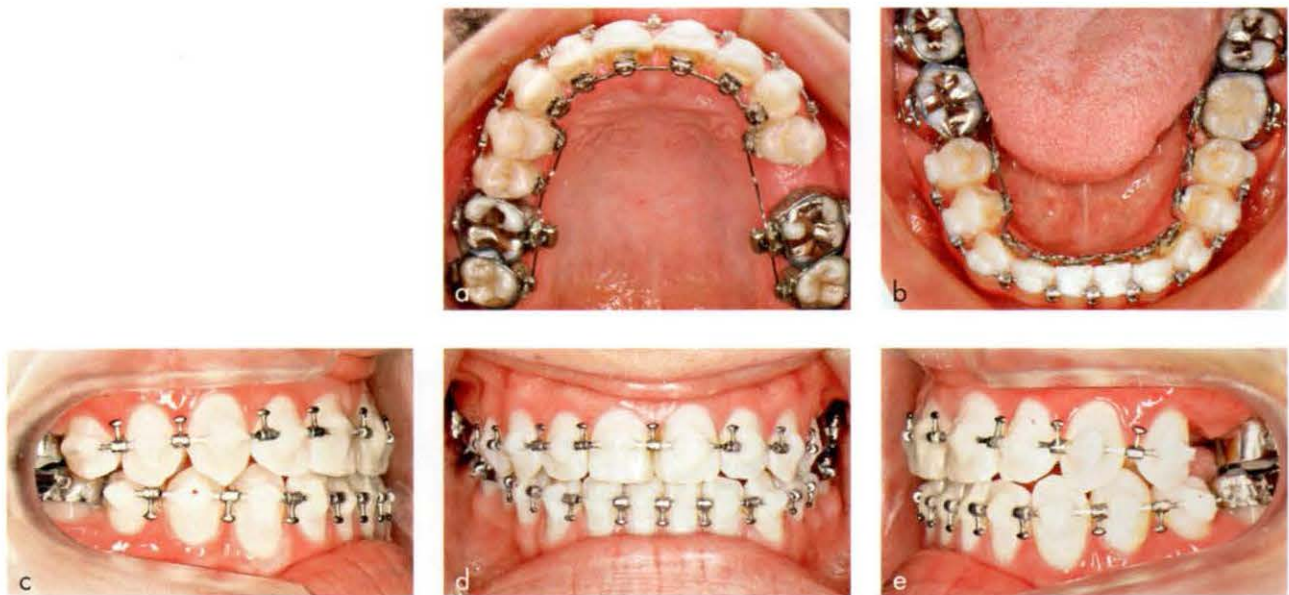
and space closure in the anterior teeth (Figs 12-40a to 12-40e).

While leveling was continued, torque establishment and presurgical torque decompensation

in both arches were initiated simultaneously with 0.016 × 0.016 NiTi wires followed by 0.0175 × 0.0175 TMA wires. Cross-elastics were used from the lingual side of the maxillary right first molar and



Figs 12-40a-e Leveling, alignment and space regaining for the maxillary second left premolar.



Figs 12-41a-e Presurgical intraoral set-up.

the buccal side of the mandibular right first molar, and from the buccal side of the maxillary left first molar and the lingual side of the mandibular left first molar. Also, 0.016 × 0.016 NiTi sectional wires were used on the buccal sides of the maxillary and mandibular right and left first and second molars for buccal control. The presurgical orthodontic treatment required about 17 months.

At the end of this time period, the width of the maxillary arch coincided with that of the mandibular arch, and the space for replacement of the maxillary left second premolar was regained. Surgical hooks for intermaxillary fixation were bonded to the labial surfaces of the teeth using resin composite in both arches (Figs 12-41a to 12-41e).



Figs 12-42a-c Postsurgical occlusion.



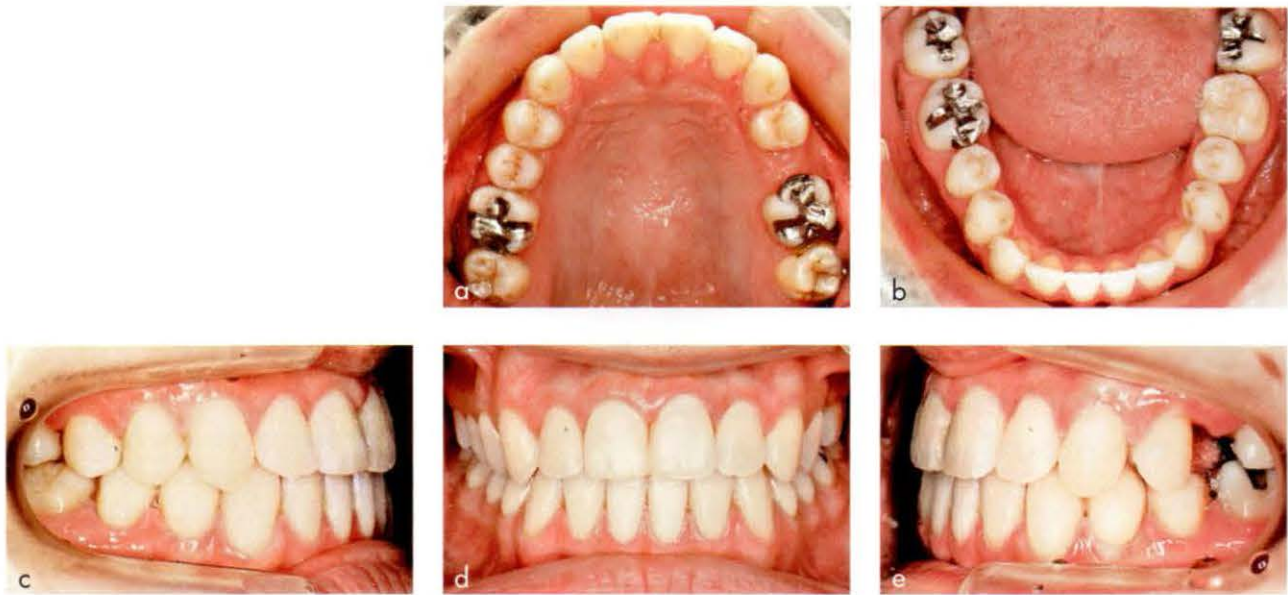
Figs 12-43a,b Case S.K. (2): Post-treatment extraoral photographs.

Sagittal split ramus osteotomy (SSRO) was performed, and the mandible was moved 3 mm to the right and 1 mm backward. After the patient was discharged, the surgical hooks were removed immediately (Figs 12-42a to 12-42e) and the patient was instructed to wear triangular elastics on the maxillary and mandibular canines and first premolars.

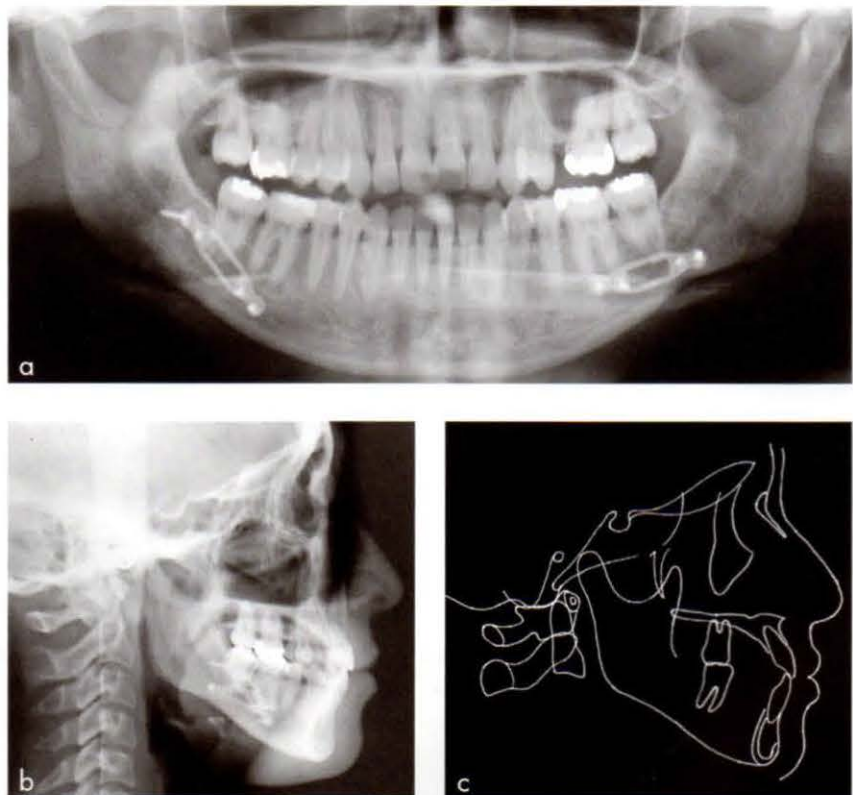
After the patient was able to open her mouth, postoperative detailing was done with 0.0175 × 0.0175 TMA wires in both arches. The use of up and down elastics was continued. Detailing required 10 months.

Post-treatment Analysis

An Angle Class I molar relationship was achieved both on the right and left sides with coincident midlines and a well-interdigitating occlusion. The extraoral and intraoral findings after appliance removal confirmed achievement of appropriate overjet and overbite, correction of the deviation of the mandible and lip distortion, although a slight amount of facial asymmetry remained. The active treatment time was 28 months (Figs 12-43 to 12-45).



Figs 12-44a-e Case S.K. (2): Post-treatment intraoral photographs.



Figs 12-45a-c Case S.K. (2): Post-treatment radiographs.

13 STB NON-EXTRACTION MECHANICS

with Luca Lombardo & Miguel Ángel Lucés León

The continuing advances in treatment mechanics and the rising demand for conservative esthetic therapies have remarkably reduced the need for extractions, even in the presence of strict discrepancies.

However, non-extraction orthodontic treatment remains one of the most controversial aspects of modern orthodontics. The biggest criticism of the non-extraction orthodontics approach is with regard to the possibility of expanding the arches beyond certain physiological limits, obtaining bodily movement of teeth (distalization) and the consequent necessity to wear a retainer for an indefinite period of time in order to guarantee the stability of the result. On the other hand, non-extraction orthodontic treatment is considered a good option in patients with little or moderate crowding or constricted dental arches with mesial and lingual tipping of the teeth, and, in a more predictable way, in young patients with remaining growth and the presence of leeway space.

In the adult patient, use of leeway space is no longer possible and different treatment mechanics and phases are required to achieve a stable occlusion and a correct function. Gaining space without extractions for the alignment and the correction of sagittal discrepancies in permanent teeth may be possible by expanding the dental arches, interproximal stripping, correction of rotations, proclination of the incisors, modifying the arch shape or distalization of the molars. In every patient the choice of the most appropriate therapeutic approach must be made following detailed and logical planning through model and cephalometric analyses.

Considerations in Non-extraction Treatment

Dental arch expansion, interproximal stripping and distalization are the most common procedures used in non-extraction treatments in adult patients.

To be more precise, the possible methods of correction in a non-extraction case include:

- increasing the length of the dental arch, by transverse arch expansion (dental or dentoalveolar) or by a sagittal expansion (proclination of the anterior teeth or distalization of the posterior teeth)
- decreasing the mesiodistal tooth dimensions through interproximal reduction or reshaping of prosthetic elements
- correction or modification of the osseous bases, which can be spontaneous (autorotation of the mandible) or orthopedically/surgically induced (Fig. 13-1).

Expansion can be obtained by the use of removable or fixed appliances and may be orthopedic expansion or the result of buccal tipping of the tooth crowns. The choice of interproximal reduction instead must be preceded by a careful evaluation of the dental anatomy (Peck and Bolton indices), with regard to the thickness of the enamel, the DMFT index, status of oral hygiene and periodontal health of the patient (Figs 13-2a to 13-2c).

Molar distalization is an orthodontic procedure that is done to increase the perimeter of the maxillary arch in the posterior segments. The maxillary molars are moved distally in order to correct a Class II molar relationship and for retracting the middle and anterior arch segments or to resolve a dentoalveolar discrepancy. It is certainly one of the most

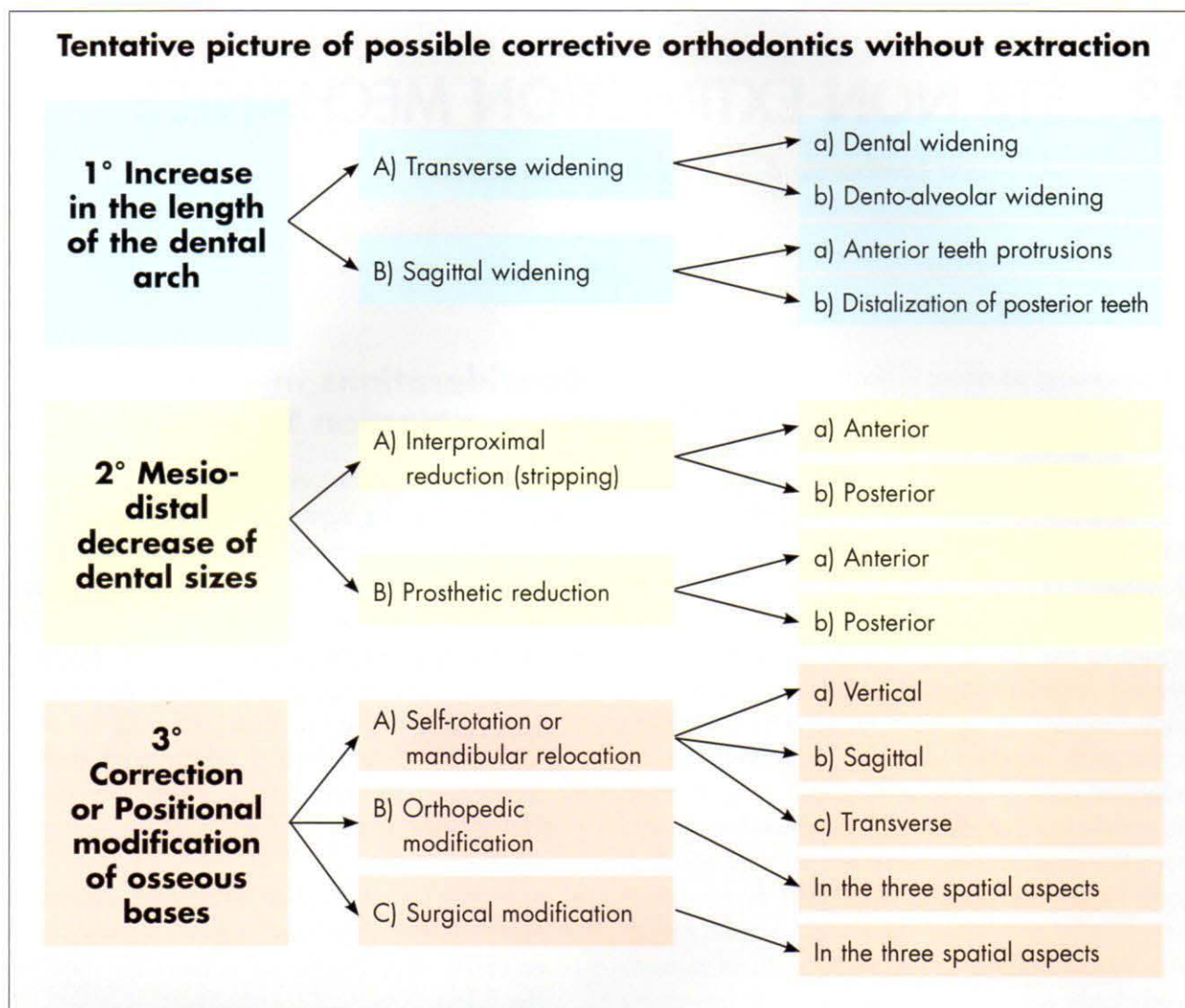
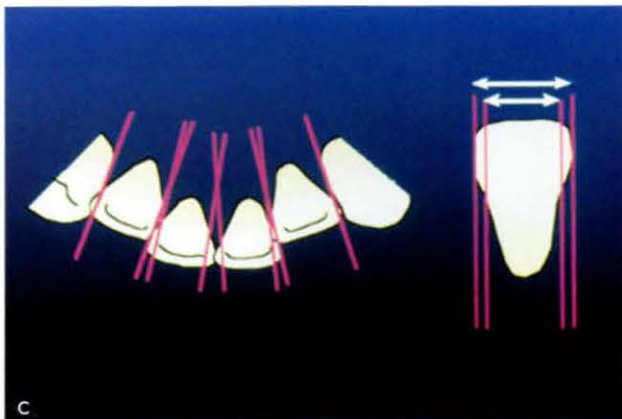
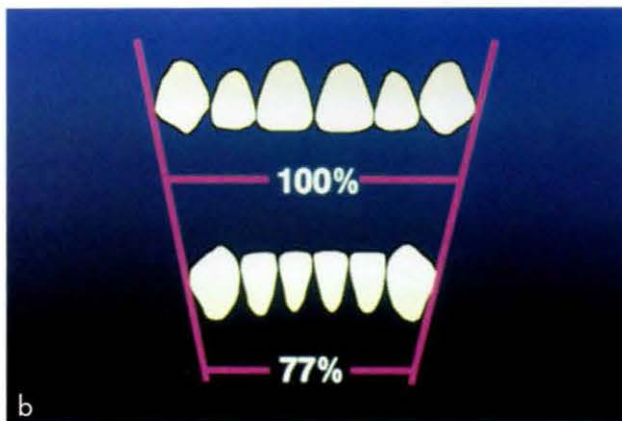
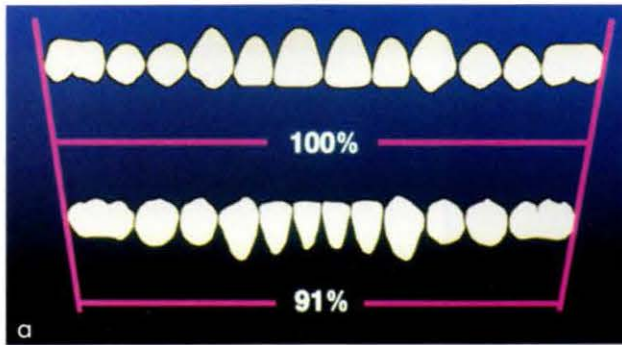


Fig. 13-1 Summary of treatment options.

effective and important ways used by the authors for the resolution of the molar Class II relationship, which represents a significant proportion of orthodontic patients. The National Health and Nutrition Estimates Survey III, which included 14,000 Americans, has estimated that 23% of children, 15% of adolescents and 13% of adults have an overjet equal to or more than 5 mm, and therefore a Class II malocclusion.

Like all the other movements that happen along the dental arch, molar distalization can be achieved by the simple movement of distal tipping of the molar

crowns, or distal bodily movement of crowns and roots, or a combination of the two movements. The choice of distalization as a therapeutic procedure for the correction of a sagittal discrepancy in adult patients has inevitable limits as an excessive skeletal discrepancy can only be resolved by surgery (ANB greater than 7 degrees – Steiner's cephalometric analysis), or the presence of pathologies involving the temporomandibular joint or health conditions that compromise the quality of the bone and health of the periodontal tissues that are contraindications to distalizing mechanics.



Figs 13-2a-c Dental anatomy evaluation.

When choosing between distalization and extraction therapy, the clinician needs to consider the type of maxillary and facial growth, the possibility of remaining growth, the current occlusal forces, the characteristics of the curve of Spee, the presence of maxillary third molars, the anatomic characteristics of the bone in the posterior maxillary regions, and the eventual need for anchorage combined with distalizing mechanics.

Molar distalization is recommended in patients with a normal or hypodivergent facial growth pattern and in patients with deep bite and/or flat profile. It is inappropriate in patients with a divergent growth pattern or skeletal open bite; in fact molar distalization can result in an increase in the vertical skeletal dimension and consequentially extrusion of the posterior dental elements, with negative consequences for the occlusal plane and mandibular position. However, this point is correct if we consider only the extrusion of the first molars during distal movement, but it is not absolutely true if the distalization occurs perfectly along the occlusal plane.

Regardless of the type of appliance we use, it is important to keep in mind that distalization of maxillary molars is limited by a few anatomic factors that always have to be considered before the beginning of orthodontic treatment.

Positions of the Second and Third Molars

An unerupted third molar whose position and direction of its long axis is favorable (Fig. 13-3a) neither delays nor complicates molar distal movement. As shown in Fig. 13-3b, a third molar whose long axis is directed away from the direction of distalization causes the operator to have to decide whether to extract it or to sacrifice the second molar which will facilitate considerably the distal movement of the first molar. Replacing the maxillary second molar with the third (Fig. 13-3b) requires that the third molar should have certain features: adequate shape, adequate crown and root sizes and favorable direction of eruption. However, there should be no doubts to extracting the second molar when there are signs of caries or the tooth has undergone endodontic treatment or crown reconstruction.

It is not wise to initiate distalization before the second maxillary molar has erupted beyond the cervical neck of the first molar (Fig. 13-4). This action causes positional changes in the unerupted teeth with a high rate of impaction and/or considerable delay in eruption. Distal inclination of the first molar with minimal bodily distalization is the predominant movement in these cases.

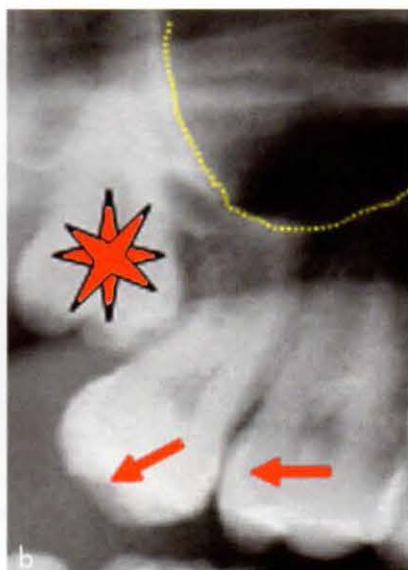
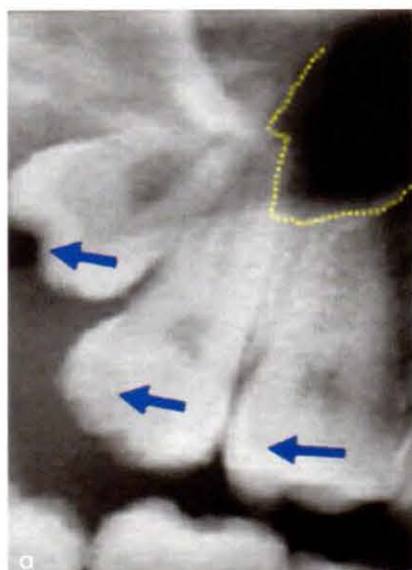


Fig. 13-3a Second and third molars without problems.

Fig. 13-3b Impacted third molar.

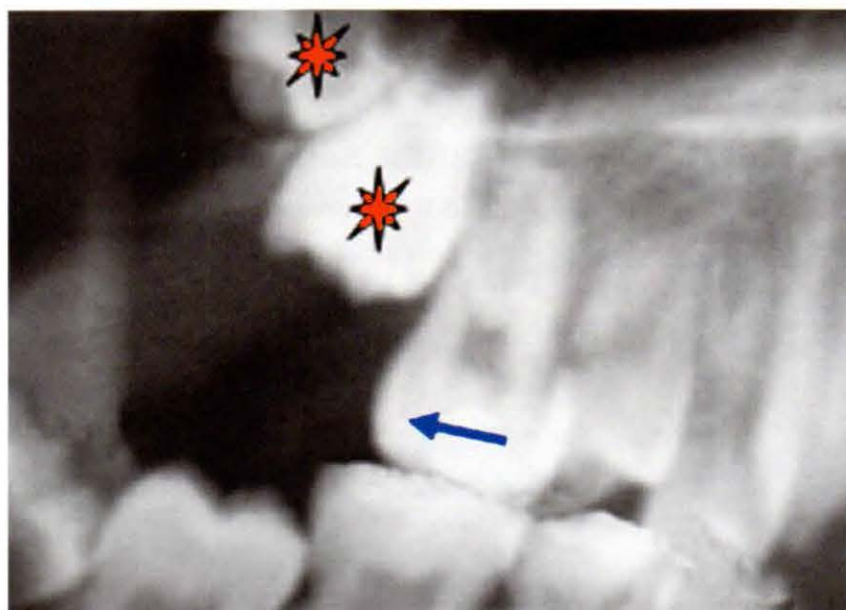


Fig. 13-4 Fully impacted second and third molars.

Maxillary Sinus

The presence of spongy bone with its abundant blood supply is a positive sign for attempting root movement; compact cortical bone with an almost avascular structure is the opposite. In a patient with an ample maxillary sinus with its floor descending and invaginating between the molars, whose roots appear to be covered by compact cortical bone, it would not be erroneous to think that these conditions are inadequate for bodily dental movement either distally or mesially (Fig. 13-5a).

When closure of mesial spaces or true distalization is intended, low maxillary sinuses complicate the movements (Fig. 13-5b), which are achieved with difficulty with unstable axial inclinations that very frequently relapse.

Posterior Crossbite

Any procedure that moves the buccal molar roots into contact with the outer bony table (cortex) will worsen the speed of the distal movement. In the

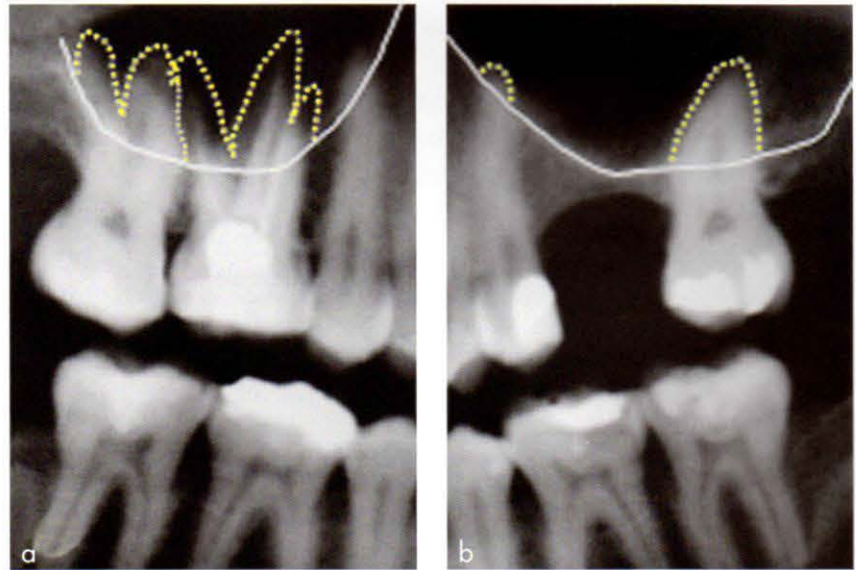


Fig. 13-5a,b Molar roots invaginating into the maxillary sinus.

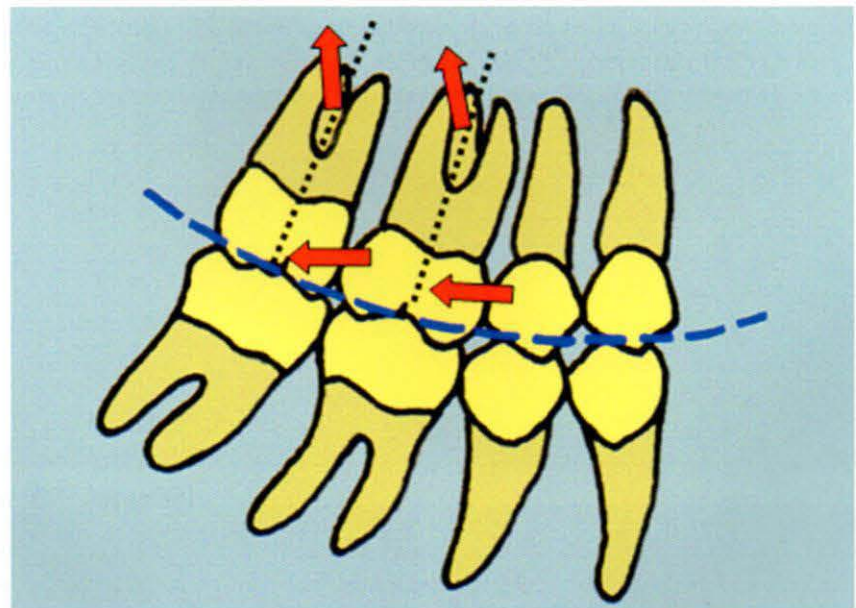


Fig. 13-6 Increased curve of Spee.

same way, correction of mesial rotations of the buccal roots before distalization is accompanied by the danger of juxtaposition of the mesial root with the compact cortex.

Owing to the oval form of the dental arches, distalization implies moving the molars and the bicusps by a greater transverse dimension. Frequently, well-conducted distalization will produce spontaneous correction of posterior crossbite.

Curve of Spee

The normal curve of Spee and any curve that is of considerable depth, pertaining to Class II malocclusions, should be leveled before any action is performed to move the molars distally. There are some important considerations with regard to the curve of Spee, such as:

- In arches with greater curvature, the longitudinal axis of the maxillary molars is vertical or even distally inclined, and this initial position is not compatible with distalization (Fig. 13-6).

- Distalization of the first and the second molars in the presence of a normal or augmented curve of Spee adds to the mechanics of distalization the need to incorporate mechanics for concomitant intrusion so that the tooth can "climb up" the curve (Fig. 13-6). If this is not done, the premature contacts that would result would cause opening of the facial axis and the danger of condylar distraction (the distally inclined position of the second molar in relation to the opening angle of the occlusion makes the situation more prone to premature contacts with the mandibular teeth). The concomitant intrusion with molar distalization (see arrows in Fig. 13-6) is the result of muscular contraction during mastication or deglutition or, owing to some persistent habitual forces, the intimate contact of the antagonistic occlusal surfaces. The forces of contraction inherent in Class II patients with brachyfacial characteristics lead to extreme muscular activity in severe cases; the strength of these forces is reduced in mesofacial patients and reduces even more in severe dolichofacial patients. Molar intrusion by either natural or mechanical forces decreases, eliminates, or corrects the risk of early contact much before the transmission of the negative effects onto the temporomandibular joint (TMJ).
- Even with an exaggerated curve of Spee, molar distalization systems that use "build up" (resins applied to the occlusal surfaces) on both maxillary premolars on both sides of the arch to disclude the teeth can result in initial distal movements that are faster. However, it may happen that with time the speed of movement decreases and, although the first maxillary molar continues to distalize without contacting, the occlusal relationship of the second molar is different. Usually, the disclusion by the "build up" is not horizontal in its total length; it decreases from the incisors to the molars because of the simple effect of mandibular rotation and the different closing curvatures. The millimetric separation of the occlusal surfaces at a level of the first premolar is minimal, specially at the ascending posterior end of the curve of Spee (distal to the second molars). This is the critical point where early contact occurs during distalization, and the place for obstructions to distalization, because the molars in their distal movement on reaching this point cause either major opening of the occlusion by mandibular rotation (in dolichofacial patients, the easier way) or the forces of muscular contraction slowly intrude the molars distally (in brachyfacial patients). The speed of distalization diminishes and two simultaneous force systems become essential: the upward (intrusion) and the distal.
- The leveled or flattened curve of Spee, besides being one of the factors that eliminate obstacles and facilitate distal movement, also contributes to the possible spontaneous mandibular autorotation, mainly in Class II patients whose initial diagnosis is referred to as "out of centricity".
- An ideally flattened curve of Spee is that which is not associated with mandibular molars with "higher" cusps owing to differences in root torque, which act as obstacles to the distalization of the maxillary molars and impede the possibility of spontaneous mandibular autorotation in the above-mentioned cases.

Exaggerated Occlusal Inclination (Plane) (Open Occlusal Angle)

Clinicians' opinions about the curve of Spee and distalization merge when this particularity is considered in patients with a dolichofacial growth pattern. A careful evaluation of the cost-benefits of extraction versus distal movement is a dilemma that these cases present.

The exaggerated occlusal inclination (because such cases do not allow leveling to flatten the curve of Spee) results in a greater area of premature first and second molar contacts during distalization (Fig. 13-7), which, along with a lesser degree of intrusive muscular forces, increases the vertical dimension through the opening of the facial axis and possible or eventual TMJ problems.

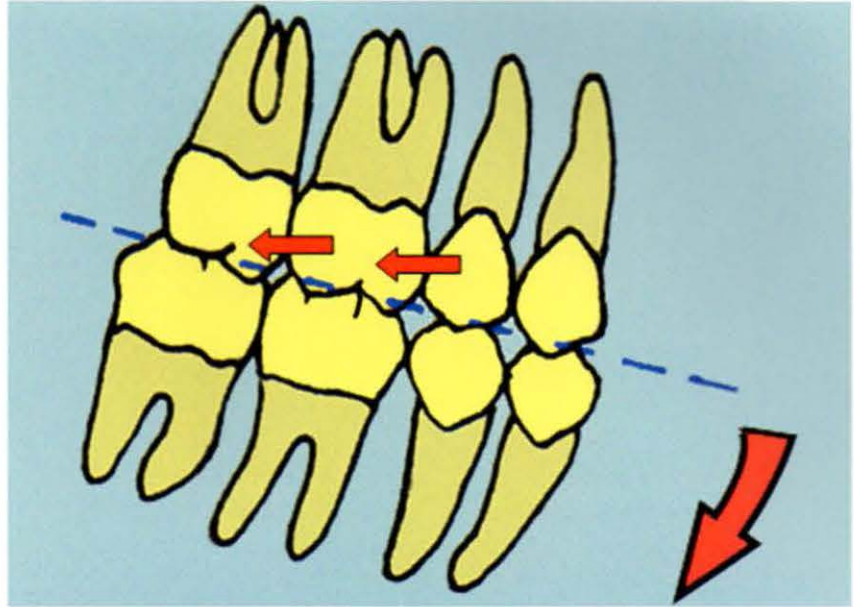


Fig. 13-7 Inclined occlusal plane.

Growing Patients

Different patterns of maxillofacial growth are encountered in the orthodontic clinic. A growing patient may be more responsive to orthopedic therapy, or to functional or physiotherapy rehabilitation. Because of the growth pattern of the lower jaw, the clinician must limit the application of distalization therapy to meso- and brachyfacial patients. According to various authors, the dolichofacial pattern can be dramatically worsened by distalization because of clockwise rotation of the mandible.

Young patients are often not cooperative and sometimes this is indeed an essential condition for the success of the treatment. Orthodontic treatment in non-compliant patients can turn into unnecessary longer treatment, cause damage to the teeth and to the periodontium, lead to more extractions, frustrate the patient and cause additional stress for the orthodontist and their staff.

Distalization Mechanics

During the past few decades, numerous techniques and new devices have been introduced for the correction of the Class II malocclusion, which have reduced the need for patient compliance. The use

of these new devices has resulted in better control of the treatment phases and consequently more predictable results. The widespread use of distalization has resulted in the evolution and creation of a great number of devices to accomplish this function.

The various distalizing devices can be distinguished from each other according to their time of appearance in the orthodontic world, their mechanism of action, being fixed or removable, for the type of force generated, and whether or not they are dependent on cooperation of the patient.

They can also be classified according to the location of their unit of anchorage into extraoral (or occipital/maxillary) and intraoral devices.

With extraoral devices (eg, headgear) there are no unwanted forces acting on the teeth.

The intraoral devices can be further subdivided into intra- and intermaxillary devices. The intramaxillary act on the maxillary arch via springs and wires, nickel titanium (NiTi) wires, and magnets, eg, Jones Jig, Pendulum Appliance, Distal jet. The intermaxillary devices make use of the antagonistic mandibular arch for this function (eg, Herbst, Jasper Jumper, Cantilever Bite Jumper, MARA, Eureka Spring, etc.).

Among all the extraoral distalizing devices the most popular is the Kloehe arch combined with different types of traction, according to the force direction

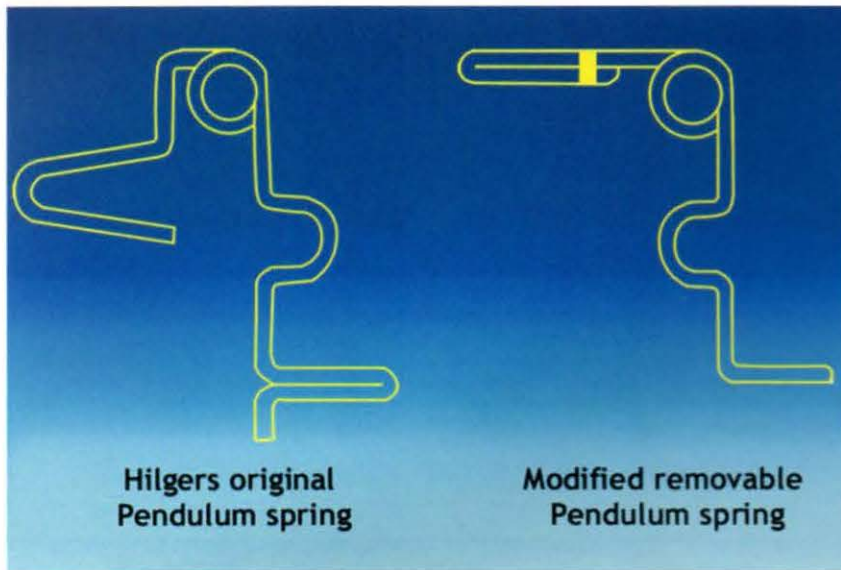


Fig. 13-8 Comparison of Hilgers' original and modified Pendulum Appliance.

required. The main obstacle to the use of this kind of device in adult patients is the necessity of total dependence on the compliance of the patient and the excessive visibility of the device.

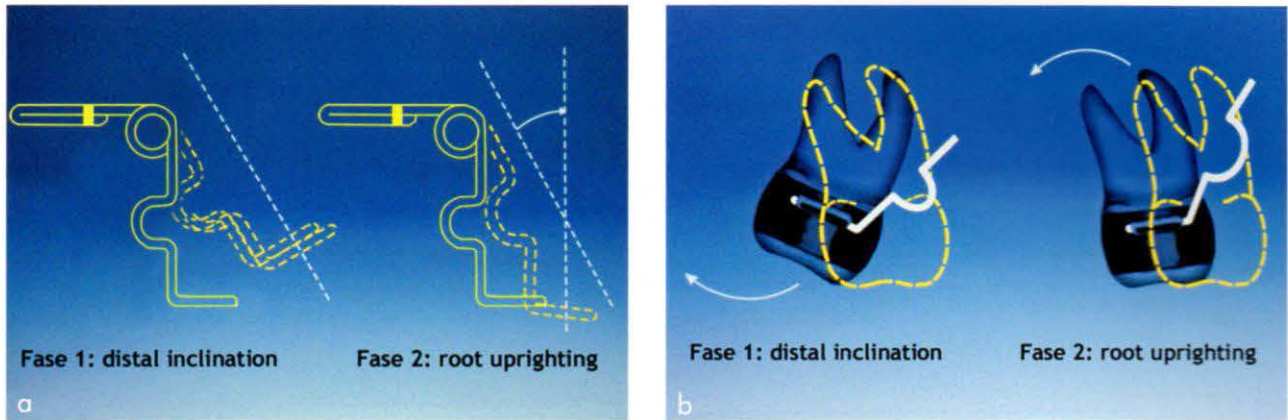
The intraoral distalizing devices are nowadays widely used and easy to manage by the orthodontist and by the patient. Although the efficacy of these devices in distalizing the maxillary molar is well documented, all of them experience a certain loss of anchorage that is evidenced by the proclination of the maxillary incisors, a consequent increase of the overjet and emphasized protrusion of the maxillary lip, change in inclination of the occlusal plane and increase in the lower facial height.

The most commonly used non-compliance intra-arch distalizing devices are the Distal jet and the Pendulum Appliance. The main advantage of these devices is that the active force acts exclusively on the maxillary arch with no effect on the mandibular arch; in their classic versions the anchorage is guaranteed by the dental arch (mesial to the molars), by the palatal Nance button and by the occlusal loads.

From the view of the patient, these devices are totally invisible and they do not interfere with phonation and eating, resulting in greater acceptability and comfort.

The Pendulum Appliance was introduced by J. Hilgers in 1992 and since then it has undergone some significant modifications of its basic construction (Fig. 13-8). The original design comprised a Nance button made of acrylic resin of 1.5 to 2 mm of thickness, which incorporates four occlusal rests that can be bonded on the deciduous molars or on the first and second premolars. The active part of the device consists of two titanium molybdenum alloy (TMA) springs (0.032), which have to be inserted into the 0.036 lingual sheaths soldered to bands on the first maxillary molars. Each spring is curved to correspond with the distal margin of the Nance button, and it is folded to form a closed helix and incorporates an omega loop for molar expansion, which is necessary to prevent posterior crossbite following distal movement of the molars. The end of each spring is extended close to the button in order to allow for a broader swinging arc of force and easier insertion in the sheath. Dr. Hilgers suggests beginning with an activation of 90 degrees of the TMA springs, based on the idea that only two-thirds of the force will be expressed by the distalizing springs while a third will get lost in the insertion of springs into the molar lingual sheaths.

There are important mechanical and biomechanical aspects of this original Pendulum design that have to be considered. The force of the TMA springs mani-



Figs 13-9a,b The effects of the modified Pendulum opening loop.

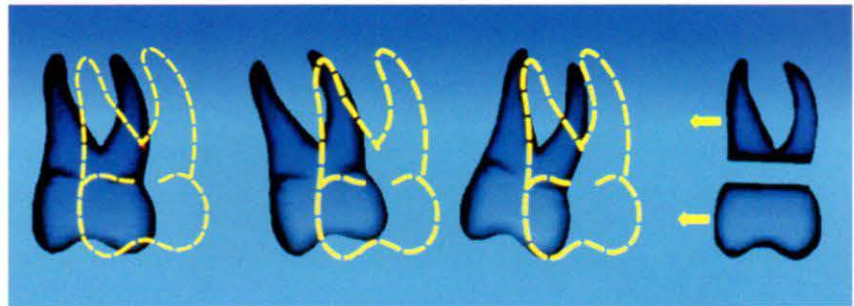


Fig. 13-10 Total distal bodily movement of the molar.

feasts itself occlusally with respect to the molars' center of resistance, inducing a relevant tipping movement of the molars, rather than a bodily movement.

Moreover, the curved movement of the springs results in mesiobuccal rotation of the molars with consequent risk of impacting the cortical maxillary bone, and the different vertical orientations of the two ends of the spring result in an unavoidable intrusive effect of the maxillary molars during distalization. In order to overcome these adverse effects numerous modifications have been proposed. The M-Pendulum, for example, introduces three important modifications to the TMA springs. The first modification is the loop direction; originally this was distally orientated, but is now mesially orientated in order to guarantee greater bodily distalization and to limit the rotation of molars (see Fig. 13-8). The opening of this loop (mesially orientated) results in distal tipping of the maxillary molar roots, counter-balancing the initial distal crown tip-

ping, as well as root uprighting (Figs 13-9a and 13-9b). Finally, a totally distal bodily movement of the molar is obtained (Fig. 13-10).

The second modification concerns the fact that the TMA springs are removable and therefore the clinician can control the amount of the force and reactivate the appliance easily (Figs 13-11a to 13-11c).

The third modification is the progressive distalization movement by activation of no more than 45 degrees, less than half suggested by Hilgers, producing a light force of about 140 g, without any reaction in the anterior teeth or the premaxilla (Fig. 13-12). According to Hilgers only two-thirds of the force will be released by the device and a third will be lost during the insertion phase.

Scuzzo and co-workers measured the horizontal and vertical forces of the modified Pendulum spring with a computer-based strain gauge system and found that the springs, activated initially by 40 to 45



Figs 13-11a-c The removable TMA springs allow the clinician to control the amount of the force and to reactivate the appliance easily.

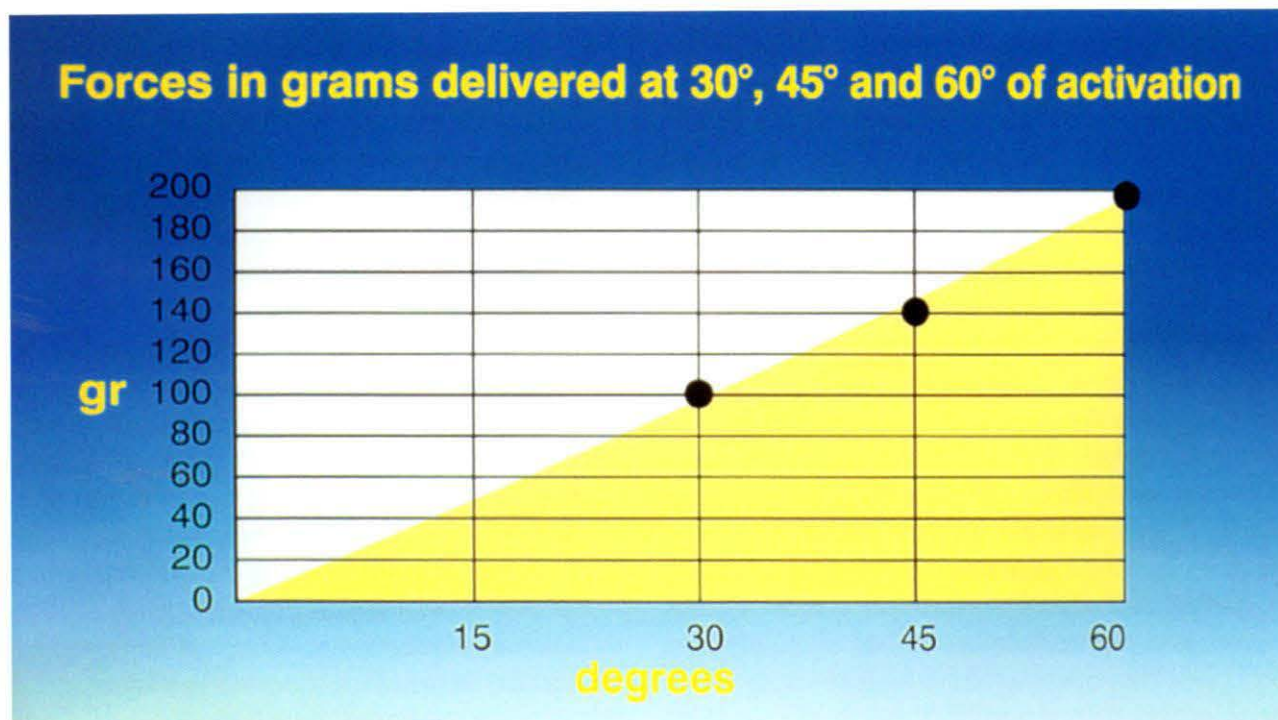


Fig. 13-12 Forces delivered by different angulations.

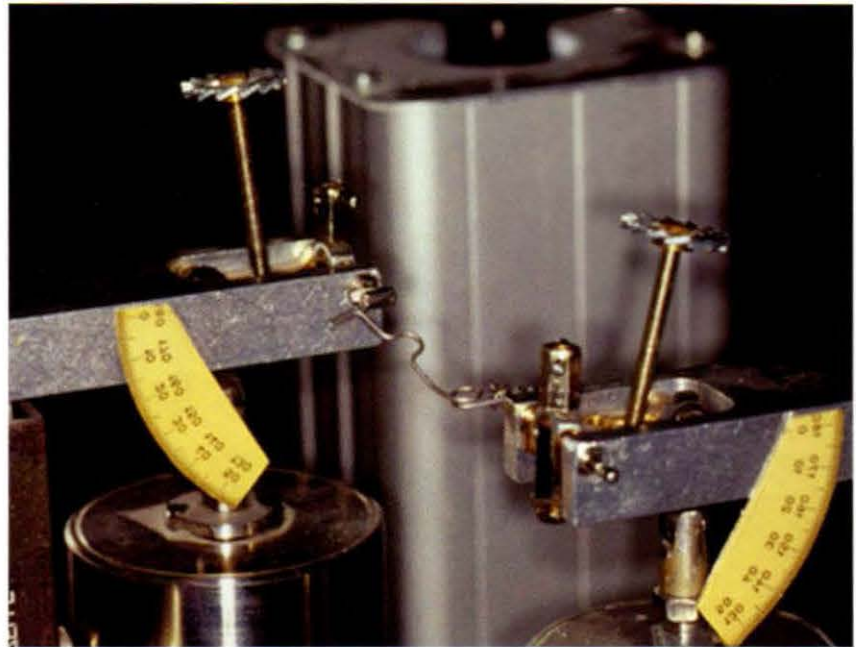


Fig. 13-13 Measuring the horizontal and vertical forces generated by the modified Pendulum spring.

Table 13-1 Modified pendulum spring: horizontal and vertical forces.

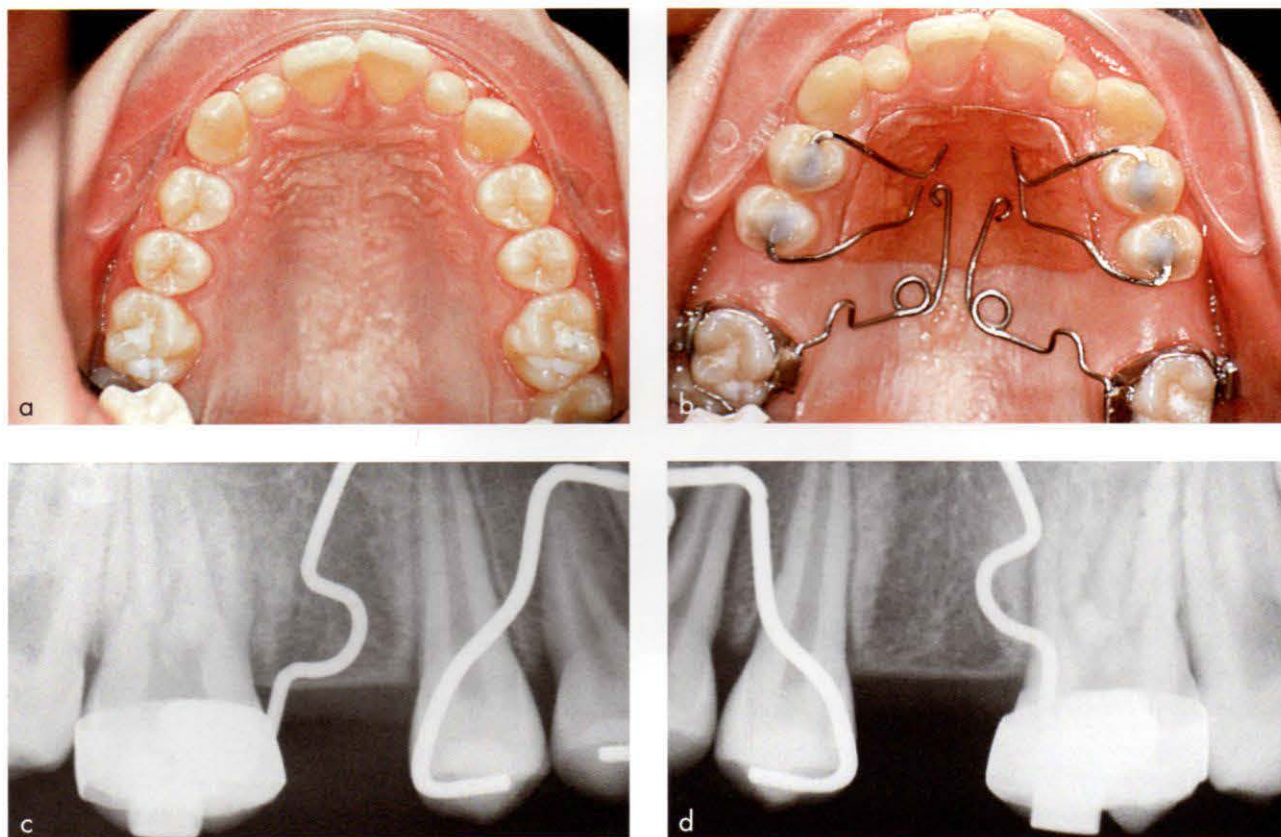
	Horizontal force (cN)		Tip-back moment (cN/mm)		Vertical force (cN)	
	Mean	SD	Mean	SD	Mean	SD
0 mm	140.2	22.9	-484.3	231.3	5.98	14
0.5 mm	112.9	24.8	-353.8	237.8	15	20
1.0 mm	85.2	27.7	-252	243.8	22.7	23.9
1.5 mm	61.8	33.6	-152.6	257.4	27.6	30.2
2.0 mm	40.9	41.1	-74.3	246.6	30	38.2

SD, standard deviation.

degrees, created a horizontal force of 140 cN, a tip-back movement of -484.2 cN, and an intrusive force of 5.98 cN on each side (Fig. 13-13). After deactivation of 2 mm a horizontal force of 40.9 cN, a tip-back movement of -74.3 cN and an intrusive force of 30 cN still remained (Table 13-1). The distalization can be achieved as a controlled tipping of the root by successive activations of the springs by 45 degrees, resulting in light forces of about 140 g, which do not strain excessively the anterior anchorage. In a clinical study on 26 subjects treated with the modified Pendulum appliance, Scuzzo and co-workers found that, in a mean period of nine months,

the maxillary first molars were moved distally by a mean of 4.8 ± 2.1 mm (range 1.3 to 8.4 mm), while maxillary first premolars were moved mesially by an average of 0.8 ± 0.7 mm (range 0 to 2.2 mm). Loss of anchorage of the premolars was 0.8 ± 1.3 mm. The intermolar distance increased by 3 ± 3.3 mm, except in one case, in which it contracted by 2 mm (Table 13-2).

According to Gosh and Nanda, there were no statistically significant differences in first molar distalization as well as anchorage loss between patients with erupted and unerupted maxillary second molars (Figs 13-14a to 13-14d).



Figs 13-14a-d There are no significant differences in first molar distalization as well as anchorage loss between patients with erupted and unerupted maxillary second molars.

Table 13-2 Distalization of maxillary first molars.

Width between	Number of cases	Median	Range	SD
First molars	26	4.8 mm	1.3 to 8.4 mm	2.1 mm
First premolars	24	0.8 mm	0 to 2.2 mm	0.7 mm
Intermolar	26	3 mm	-2.2 to 10.4 mm	3.3 mm

SD, standard deviation.

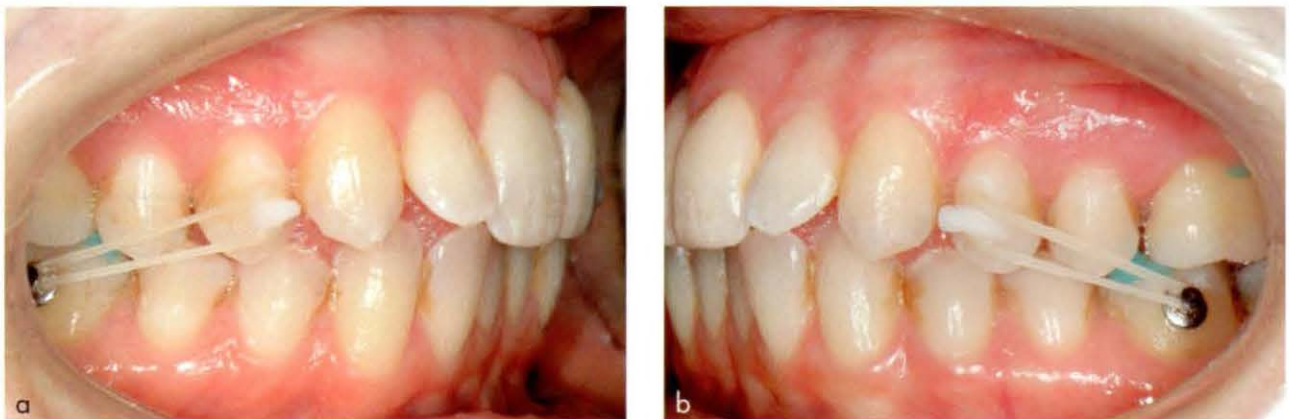
Maintenance of Anchorage

Once the maxillary first molars are in **super-Class I** in relation to the mandibular first molars, it is necessary to maintain this molar relationship. The space gained will be used to retract both premolars and canines, and/or, subsequently, will allow en-masse retraction of anterior teeth by means of a lingual multi-bracket appliance. In order to maintain the anchorage it is possible to block off the TMA springs with some resin or remove the pendulum and

insert a Nance button or a lingual arch along with miniscrews. Another solution is to add occlusal stops on the mandibular first molars using glass ionomer cement, in order to maintain the position of the distalized maxillary molars, using just the occlusal force as reinforcement of the anchorage (Figs 13-15a to 13-15d). Premolars will drift distally by themselves, helped by using short Class II elastics with very light force, in a Class I premolar relationship (Figs 13-16a and 13-16b).



Figs 13-15a-d Making occlusal stops on the lower first molars using glass ionomer cement.



Figs 13-16a,b Helping premolars to drift distally into a Class I premolar relationship by using short Class II elastics with very light force.



Figs 13-17a,b Using miniscrews to prevent mesial movement of the premolars during distalization, with no loss of anchorage.

Today, thanks to the use of the miniscrews it is possible to correct the Class II relationship with distalization and no loss of anchorage. The miniscrews, in fact, can be used as indirect anchorage in order to prevent mesial movement of the premolars during distalization. In such cases it is necessary to place the miniscrews (length 8 mm and thickness 1.3 to 1.5 mm) palatally, in the space between the first molars and premolars and "fix" them to the premolars with metal ligature ties to prevent anchorage loss (Figs 13-17a and 13-17b). If this is not possible, a further M-Pendulum modification can be made by inserting the miniscrews into the button (2 mm and 9 to 11 mm length) thereby creating direct skeletal anchorage.

Conclusion

Non-extraction lingual orthodontic treatment requires a constant balance between esthetics and function and must take into account a patient's needs. Today, satisfying such demands as well as respecting the biological limits of the maxillary complex is a challenge that the clinician can easily overcome. The availability of effective distalizing appliances that do not compromise the patient from an esthetic and social point of view have made Class II malocclusion treatment positive and predictable.

14 ILLUSTRATIVE STB NON-EXTRACTION CASES

Case V.R.

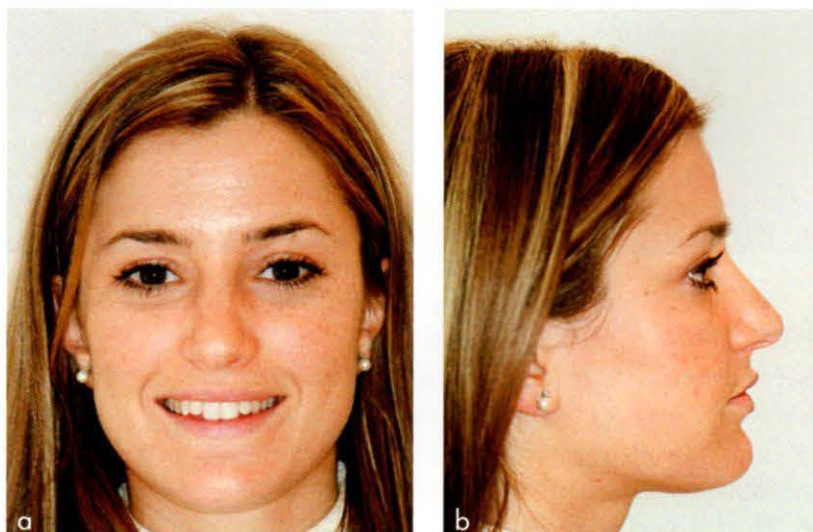
Chief Complaint, Examination Findings, and Diagnosis

A woman aged 25 years 7 months at the initial visit requested invisible orthodontic treatment to improve her smile, from both an aesthetic and an occlusal point of view. On examination she had skeletal Class I malocclusion, with a flat profile and a slightly prominent chin. Both lips were in good position. The frontal view showed a symmetric face and her smile showed the maxillary anterior crowding (Figs 14-1a and 14-1b).

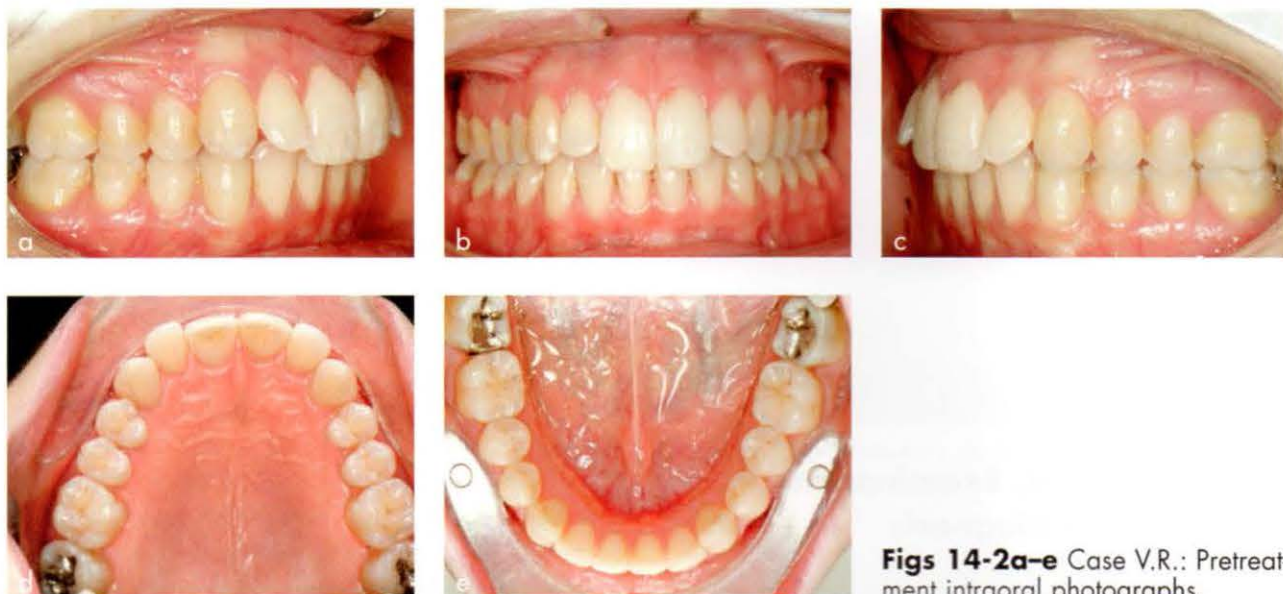
Intraorally, she had Angle Class II division 2 malocclusion with anterior deep bite (overbite 4 mm) and slight crowding in both arches. The maxillary third molars were erupted but the mandibular third

molars were missing. The maxillary central incisors were tipped lingually while the lateral incisors had a labial inclination. The overjet was 6 mm as measured from the lateral incisors. The transverse relationship of the arches was normal (Figs 14-2a to 14-2e).

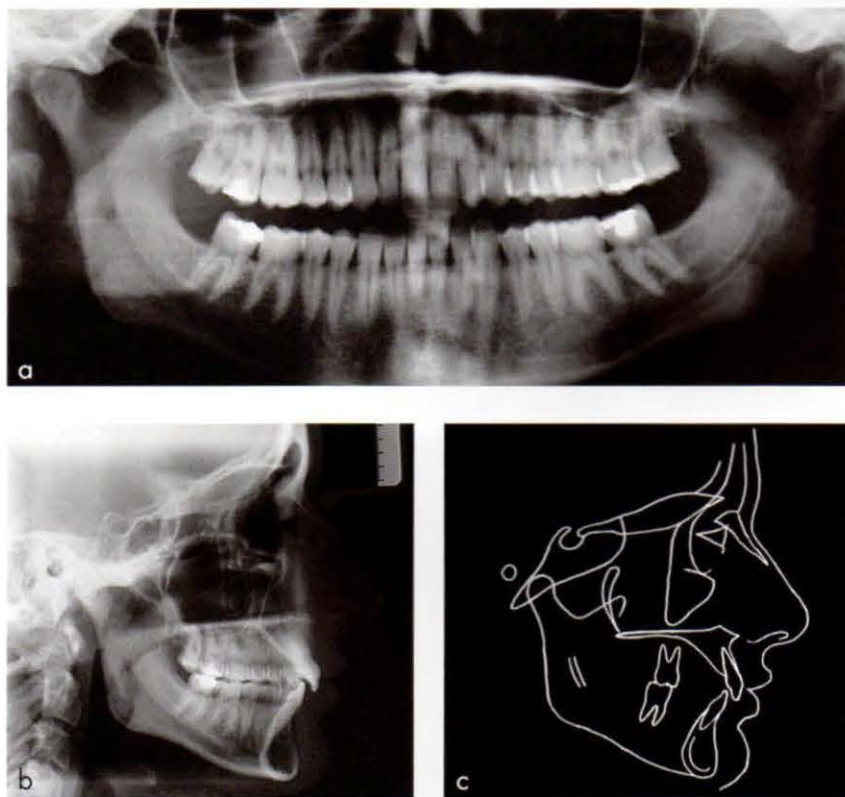
The lateral cephalometric analysis confirmed the skeletal Class I (A-N-Pg 1.5 degrees) with normal vertical relationship (S-N /Go-Gn 32 degrees). The dentoskeletal analysis showed that the maxillary incisors were in lingual inclination (1/ANS-PNS 103.5 degrees) with acceptable inclination of mandibular incisors (1/Go-Gn 102 degrees, 1/A-Pg 1mm). The interincisal angle was in the normal range (132 degrees). The profile was balanced with a nasolabial angle of 102 degrees. In reference to Ricketts' E line, the upper lip position was -6 mm and the lower lip position was -5 mm (Figs 14-3a to 14-3c).



Figs 14-1a,b Case V.R.: Pretreatment extraoral photographs.



Figs 14-2a-e Case V.R.: Pretreatment intraoral photographs.



Figs 14-3a-c Case V.R.: Pretreatment radiographs.

Treatment Plan

- Extraction of maxillary third molars.
- Distalization of maxillary molars to achieve Class I relationship.
- Alignment and leveling.
- Class II mechanics.
- Correction of dental inclination and establishment of the torque, particularly in the anterior area.
- Alignment of the maxillary and mandibular midlines with the facial midline.
- Finishing and detailing.
- Post-treatment retention.



Fig. 14-4 Upper molar distalization with the M-Pendulum appliance.



Fig. 14-5 Aligning and leveling in the mandibular arch (0.012 NiTi and 0.016 TMA archwires) with gentle stripping in the anterior area.



Figs 14-6a-d Occlusal build-ups on 36 and 46 acting as stops to prevent maxillary first molars mesialization.

Key Treatment Points

- Maintaining a good position of the upper lip and a good nasolabial angle during the orthodontic therapy.
- Use of STb lingual appliance for the treatment in keeping with the patient's request for an esthetic appliance.

Treatment Details

Stage 1

- Extraction of maxillary third molars.
- M-Pendulum appliance for maxillary molars distalization (Fig. 14-4).
- Mandibular STb lingual appliance fitted.

- Mandibular aligning and leveling (0.012 nickel titanium [NiTi], 0.016 titanium molybdenum alloy [TMA] archwires) with slight stripping of the anterior teeth (Fig. 14-5).

Stage 2

- Removal of the M-Pendulum appliance at the end of maxillary molar distalization.
- Occlusal build-up on the right and left mandibular first molars as stops to prevent mesialization of the maxillary first molars (Figs 14-6a to 14-6d).
- Distalization of maxillary premolars and canines mainly by drifting, enhanced by the use of very light Class II elastics (Figs 14-7a to 14-7d).



Figs 14-7a-d Use of very light Class II elastics to enhance drifting.



Figs 14-8a,b Upper arch aligning and leveling with 0.012 NiTi and 0.016 TMA archwires.



Figs 14-9a,b Establishment of the torque and space closure with 0.0175 x 0.0175 TMA archwires.

Stage 3

- Maxillary STb lingual appliance fitted.
- Maxillary aligning and leveling (0.012 NiTi and 0.016 TMA archwires) (Figs 14-8a and 14-8b).

Stage 4

- Maxillary and mandibular 0.0175 x 0.0175 TMA archwires for establishment of torque and space closure (Figs 14-9a and 14-9b).

Stage 5

- Maxillary and mandibular 0.016 TMA archwires for finishing and detailing.
- Debonding and retention with a clear removable retainer in the maxillary arch and a fixed retainer in the mandibular arch.

Figs 14-10a,b Case V.R.: Post-treatment extraoral photographs.



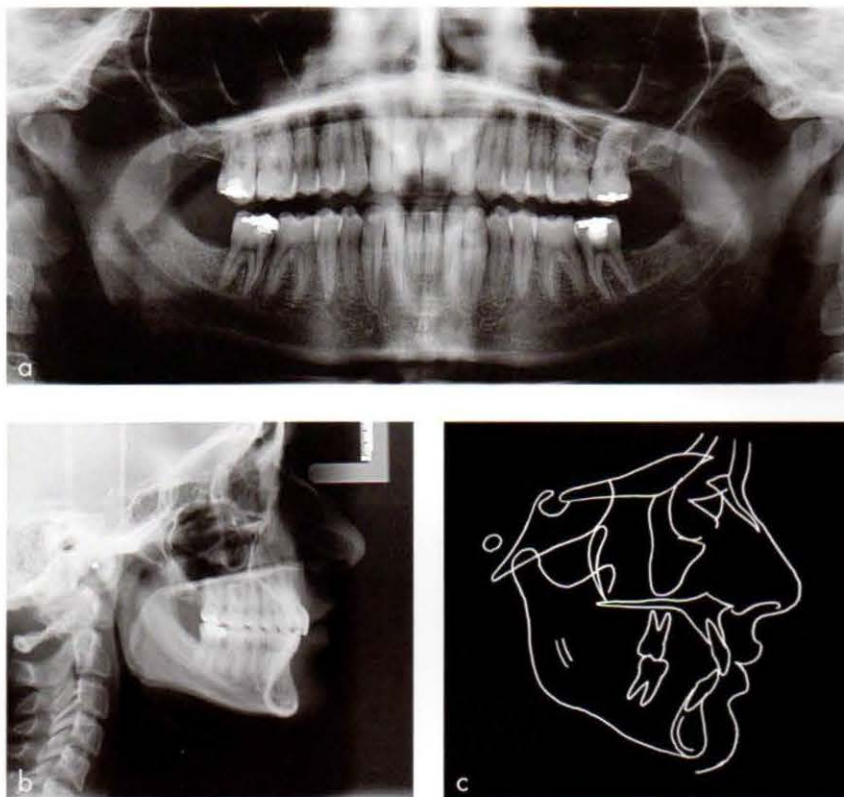
Figs 14-11a-e Case V.R.: Post-treatment intraoral photographs.

Post-treatment Analysis

The treatment objectives were fully achieved. The profile slightly improved (nasolabial angle: 100 degrees; upper lip position -5 mm; lower lip position -4 mm). The smile was improved and the patient was fully satisfied with the results (Figs 14-10a and 14-10b).

The full Class II molar and canine relationships were corrected to Class I and the maxillary and

mandibular incisors were placed in a good position. Both arches were leveled and aligned with normal overjet (2.5 mm) and overbite (2 mm) (Figs 14-11a to 14-11e). The maxillary incisor inclination was corrected (I/ANS-PNS 110 degrees), the mandibular incisor labial inclination slightly increased (I/Go-Gn 106 degrees), but their compensation improved (I/A-Pg 2 mm) (Figs 14-12a to 14-12c). The posterior intercuspation was



Figs 14-12a-c Case V.R.: Post-treatment radiographs.

improved and the dental and facial midlines were coincident. Good incisal guidance and canine protection were achieved.

Maximum esthetics were maintained during the entire treatment period with the use of the lingual appliance. The active treatment time was 20 months.

Case A.P.

Chief Complaint, Examination Findings, and Diagnosis

A girl aged 14 years 11 months desired improving her smile with reduction in the overjet and improvement in her facial esthetics. She also requested invisible orthodontic treatment. She had already undergone 4-year orthodontic treatment.

At the initial visit, profile analysis of the patient showed a skeletal Class II malocclusion with a retrognathic mandible, large nasolabial angle, and a dolichofacial pattern. In the frontal view, a slight mandibular asymmetry was evident (due to the scissors bite on the right side) (Figs 14-13a and 14-13b). The upper lip was in an acceptable position, while the lower lip was everted and the labiomental fold was accentuated.

No objective or subjective temporomandibular joint problems were elicited, despite the scissors bite and retruded mandibular position.

On intraoral examination she had a severe Class II division 1 malocclusion, scissors bite on the right side with a slightly collapsed mandibular arch on the same side, mild anterior crowding, anterior deep bite (5 mm) and increased overjet (8 mm) (Figs 14-14a to 14-14e). Both maxillary and mandibular third molars were missing.

Cephalometric analysis showed a severe skeletal Class II (A-N-Pg 8 degrees) with a vertical dolichofacial pattern (S-N/Go-Gn 40 degrees). The maxillary incisors were labially inclined (I/ANS-PNS 119 degrees) while the mandibular incisors were within the normal range (I/Go-Gn 98 degrees, I/A-Pg 1mm). As a consequence, the interincisal angle was significantly reduced (116 degrees). Examination of the soft tissues profile revealed an increased nasolabial angle (115 degrees). With reference to Ricketts' E line, the upper lip was in a good position (-3 mm) and the lower lip was protruded (+1.5 mm) (Figs 14-15a to 14-15c).

Treatment Plan

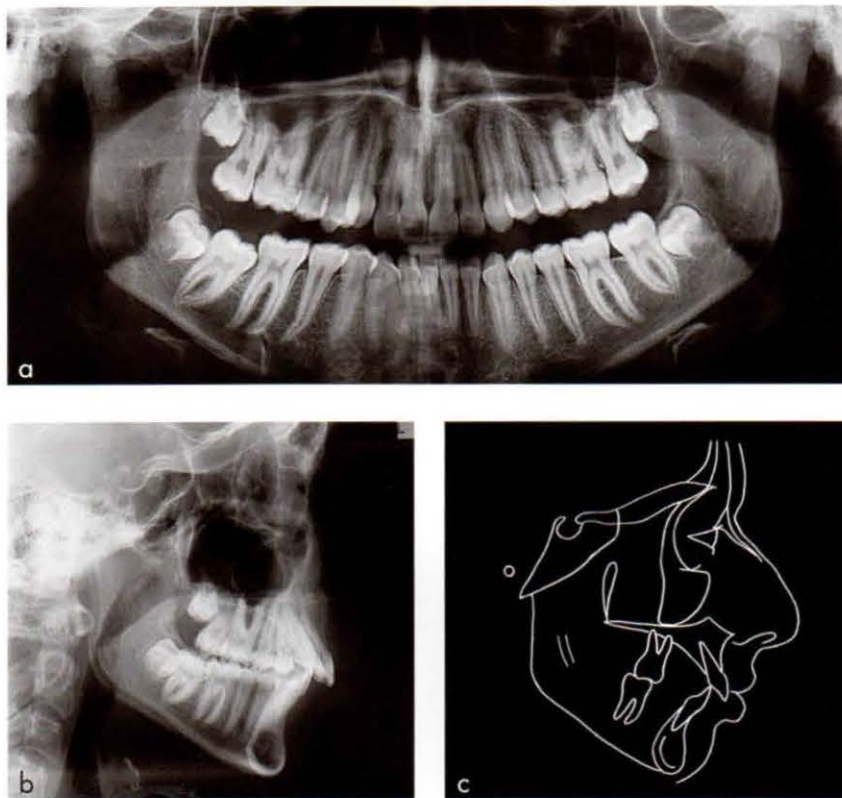
- Orthodontic preparation and coordination of the maxillary and mandibular arches.
- Functional orthopedic mandibular advancement, with the expectation that residual growth would help resolve the malocclusion.
- Maxillary and mandibular midlines aligned with the facial midline and reduction of the facial asymmetry with a centered mandibular position.
- Correction of dental inclination and establishment of the torque, particularly in the anterior area.
- Finishing and detailing.
- Post-treatment retention.



Figs 14-13a,b Case A.P.: Pre-treatment extraoral photographs.



Figs 14-14a-e Case A.P.: Pre-treatment intraoral photographs.



Figs 14-15a-c Case A.P.: Pre-treatment radiographs.

The treatment plan was based on non-extraction therapy. Extractions would have increased the nasolabial angle further with a negative effect on the patient's profile. It was decided to use the STb

lingual appliance as the patient had already worn a labial appliance for 4 years and she had requested an invisible appliance.



Figs 14-16a-c Herbst appliance for functional orthopedic mandibular advancement.



Figs 14-17a-c Herbst appliance removed.



Figs 14-18a-c Finishing and detailing with 0.016 TMA archwires.

Key Treatment Points

- Avoidance of premolar extraction to enable improvement of the facial profile.
- Use of STb lingual appliance for the treatment following the patient's request for an esthetic appliance.

Treatment Details

Stage 1

- Maxillary and mandibular aligning and leveling (0.012 NiTi, 0.016 TMA).
- Correction of right lateral scissors bite.
- Maxillary and mandibular 0.0175 × 0.0175 TMA for torque establishment.

- Transverse coordination of maxillary and mandibular arches in a protrusive occlusion, to achieve a dental Class I relationship.

Stage 2

- Herbst appliance used for functional orthopedic mandibular advancement (Figs 14-16a to 14-16c).

Stage 3

- Herbst appliance removed (Figs 14-17a to 14-17c).
- Maxillary and mandibular 0.016 TMA archwires for finishing and detailing (Figs 14-18a to 14-18c).



Figs 14-19a,b Case A.P.: Post-treatment extraoral photographs.



Figs 14-20a-e Case A.P.: Post-treatment intraoral photographs.

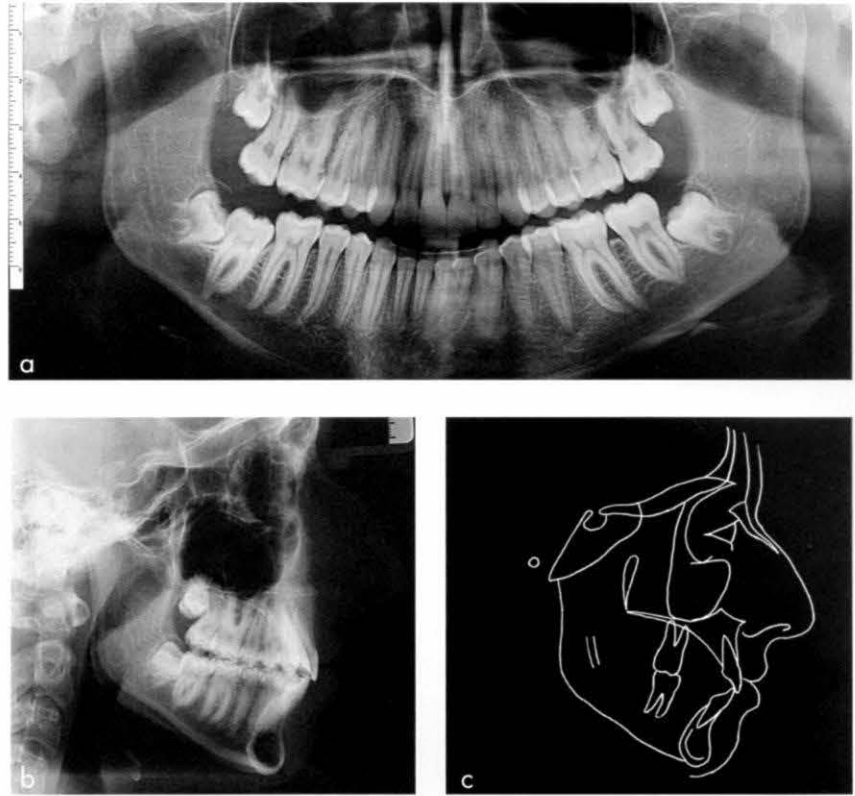
- Debonding and retention with clear removable retainer in the maxillary arch and a fixed retainer in the mandibular arch.

Post-treatment Analysis

The treatment objectives were achieved. The residual growth with the use of the Herbst appliance helped to achieve a skeletal Class I facial pattern; the facial balance was also significantly improved. In particular, the mandibular position was significantly advanced, the nasolabial angle had decreased,

and the lower lip had retruded to a good position. The smile was improved (Figs 14-19a and 14-19b) and the patient and her parents were fully satisfied with the results.

The severe bilateral dental Class II relationship was corrected to Class I (molar and canine) and the scissors bite on the right side was corrected. Both maxillary and mandibular arches were leveled and aligned with a good overjet and overbite. Occlusal intercuspation was improved both in the anterior and in the posterior areas (Figs 14-20a to 14-20e).



Figs 14-21a-c Case A.P.: Post-treatment radiographs.

The post-treatment cephalometric analysis confirmed the achievement of a skeletal Class I facial pattern (A-N-Pg 3.5 degrees), with slight improvement in vertical relations (S-N/Go-Gn 38 degrees). The maxillary incisor protrusion was reduced (I/ANS-PNS 108 degrees), whereas the mandibular incisor labial inclination was slightly increased (I/Go-Gn 102 degrees) but their position was still within the accepted range (I/A-Pg 4mm). The interincisal angle was reduced (124 degrees) and normal overjet (3mm) and overbite (2mm) achieved. Regarding the profile analysis, both the

nasolabial angle (109 degrees) and the lower lip protrusion (-2mm) had reduced to fall within the normal range (Figs 14-21a to 14-21c).

Good esthetics were maintained during the treatment with the use of the lingual and Herbst appliances. A fixed lingual retainer was bonded in the mandibular arch to prevent relapse of anterior crowding. A clear removable retainer with an anterior inclined bite plane was used to help keep the mandible in a forward position until the end of growth. The active treatment time was 15 months.

Case G.R.

Chief Complaint, Examination Findings, and Diagnosis

A girl aged 14 years 7 months complained of crowded anterior teeth. On extraoral examination the patient showed a balanced profile with a skeletal Class I malocclusion. The upper and lower lips were in a good position. The frontal view showed a symmetric face but the smile was constrained and showed the maxillary anterior crowding with midline deviation (Figs 14-22a and 14-22b).

On intraoral examination, the maxillary and mandibular central incisors were crowded with molar and canine Class I relationships and a unilateral crossbite on the right side. The transverse occlusal relationship was deviated because of the right posterior crossbite. Both the overjet (2 mm) and the overbite (3 mm) were normal (Figs 14-23a to 14-23e).

The lateral cephalometric analysis confirmed the skeletal Class I (A-N-Pg 2 degrees) malocclusion with normal vertical relationships (S-N/Go-Gn 34 degrees). The dentoskeletal analysis showed normal

inclination of the maxillary incisors (1-ANS-PNS 110 degrees) with slight lingual inclination of mandibular incisors (1-Go-Gn 86 degrees, 1-A-Pg 2mm). The interincisal angle was in the normal range (136 degrees). The profile was balanced (nasolabial angle 112 degrees) (Figs 14-24a to 14-24c).

Treatment Plan

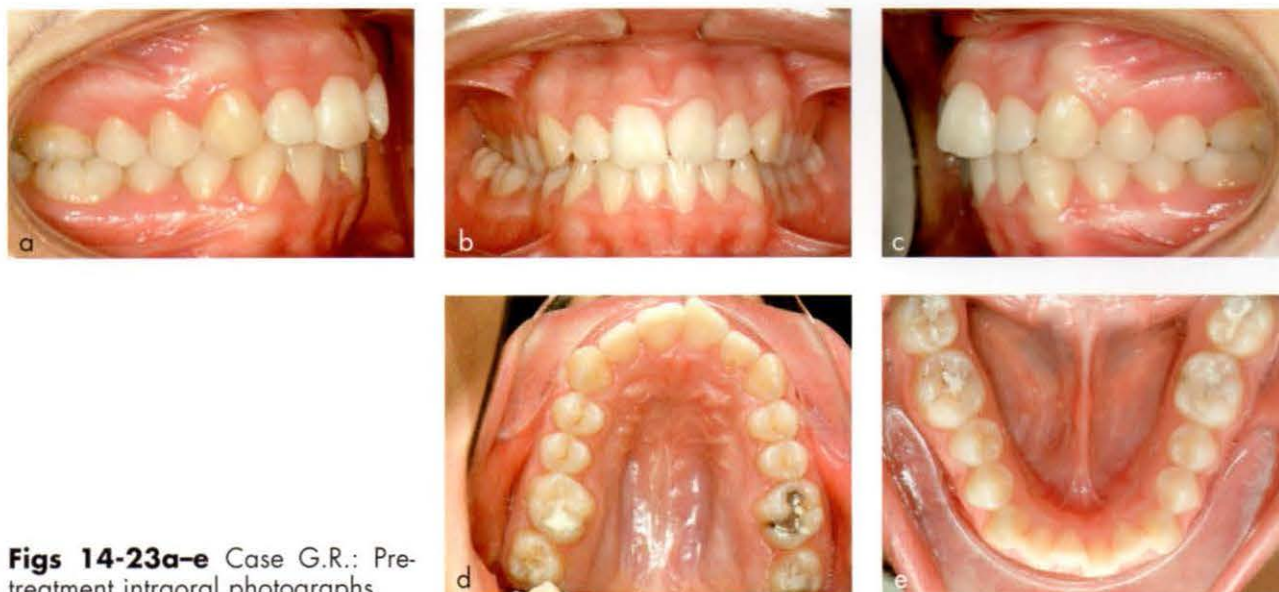
- Expansion of the maxillary arch for crossbite correction.
- Alignment and leveling of both dental arches.
- Alignment of the maxillary and mandibular midlines with the facial midline.
- Finishing and detailing.
- Post-treatment retention.

Key Treatment Points

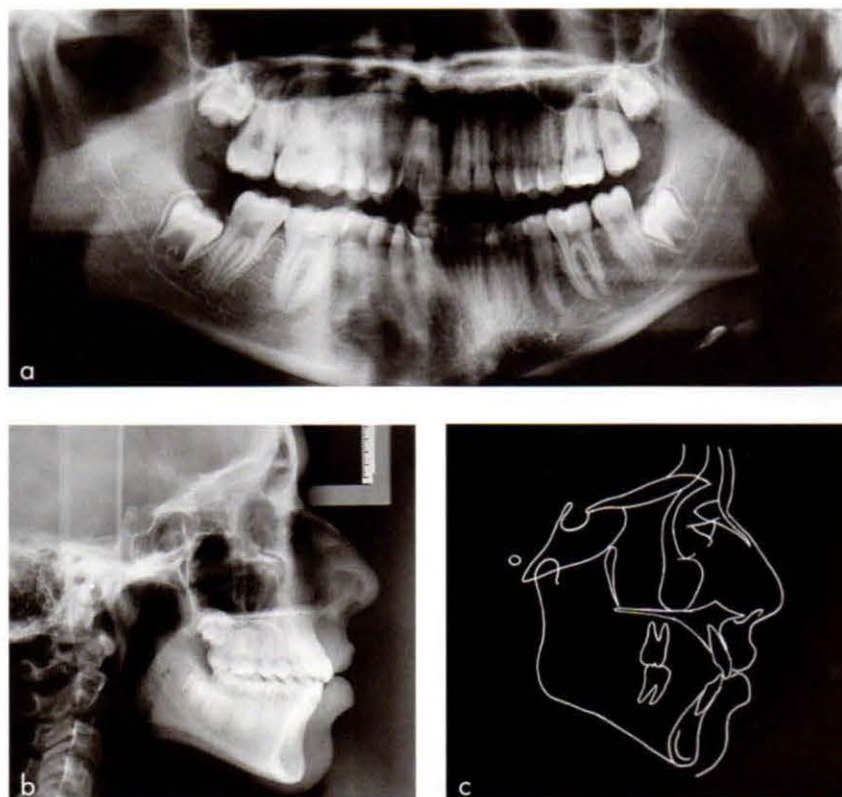
- Maintenance of the good position of the upper lip and the nasolabial angle during the treatment phase.
- Use of STb lingual appliance for the treatment following the patient's request for an esthetic appliance.



Figs 14-22a,b Case G.R.: Pre-treatment extraoral photographs.



Figs 14-23a-e Case G.R.: Pre-treatment intraoral photographs.



Figs 14-24a-c Case G.R.: Pre-treatment radiographs.



Figs 14-25a,b Aligning and leveling with 0.012 NiTi archwires.



Figs 14-26a,b Rotational control with 0.014 NiTi archwires.



Figs 14-27a,b Finishing and detailing with up and down elastics and 0.016 TMA archwires.

Treatment Details

Stage 1

- Quad-helix for maxillary arch expansion.

Stage 2

- Maxillary and mandibular STb lingual appliance.
- Maxillary and mandibular aligning and leveling (0.012 NiTi archwires) (Figs 14-25a and 14-25b).

Stage 3

- Maxillary and mandibular 0.014 NiTi archwires for rotational control (Figs 14-26a and 14-26b).

Stage 4

- Maxillary and mandibular 0.016 TMA archwires with up and down elastics for orthodontic finishing and detailing (Figs 14-27a and 14-27b).
- Debonding and retention with a clear removable

Figs 14-28a,b Case G.R.: Post-treatment extraoral photographs.



Figs 14-29a-e Case G.R.: Post-treatment intraoral photographs.



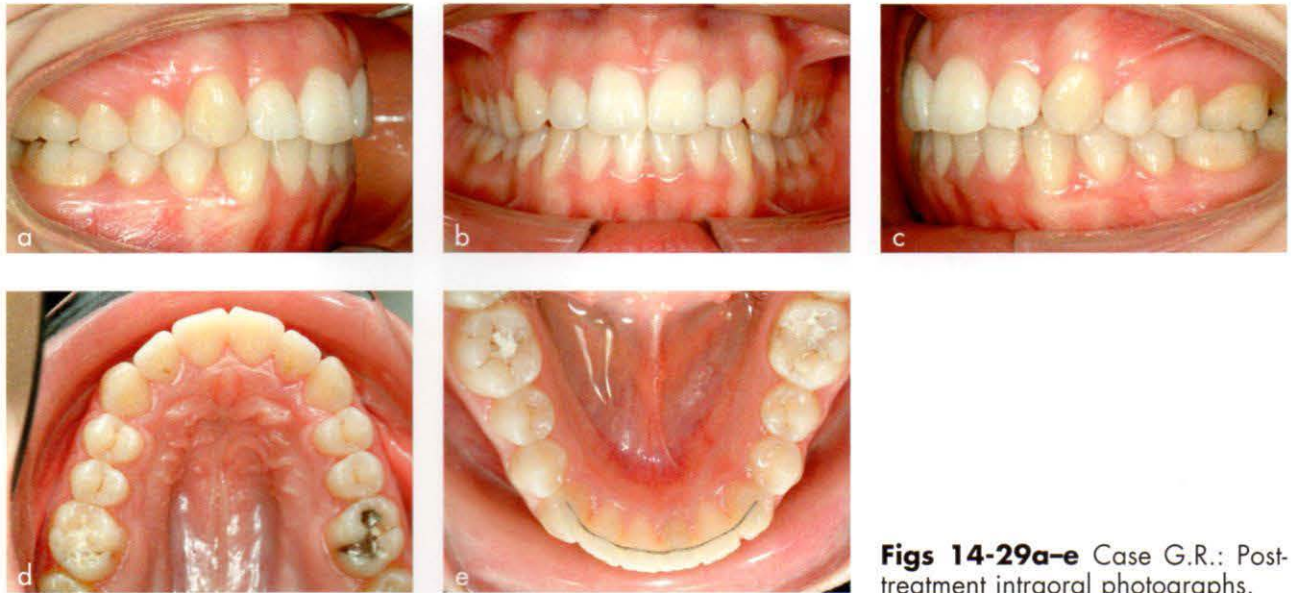
retainer in the maxillary arch and a fixed retainer in the mandibular arch.

Post-treatment Analysis

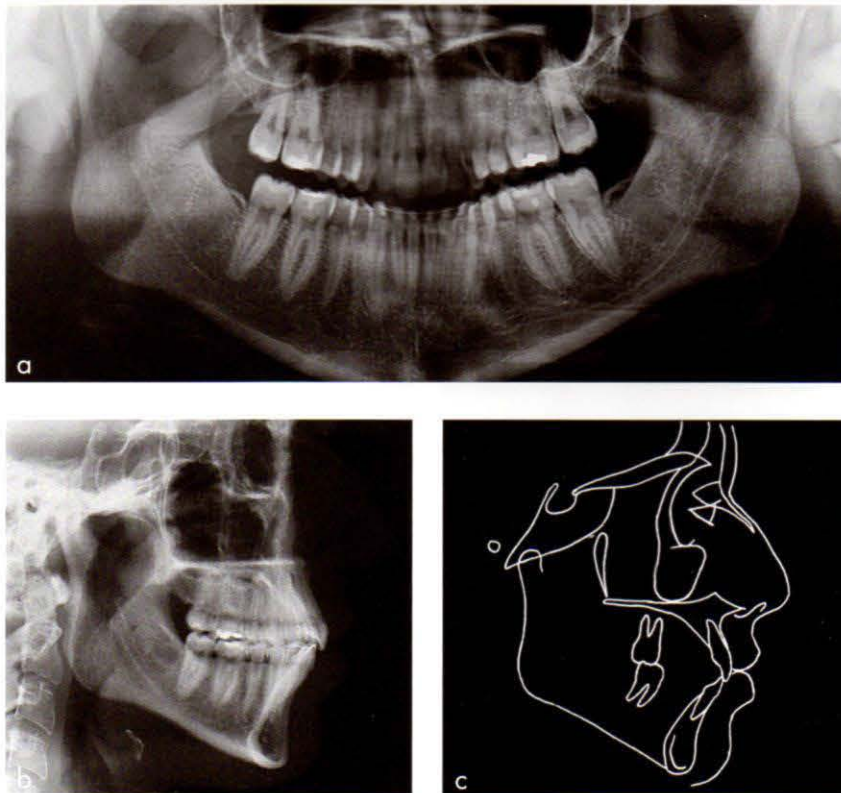
The treatment objectives were fully achieved. The patient's smile improved and the patient was fully satisfied with the results (Figs 14-28a and 14-28b). Both arches were leveled and aligned with good overjet and overbite. The posterior intercuspation

was improved because of crossbite correction and the dental and facial midlines were coincident (Figs 14-29a to 14-29e). Good incisal guidance and canine protection were achieved.

The post-treatment cephalometric analysis showed that the maxillary incisor lingual inclination was maintained (1-ANS-PNS 110 degrees), the mandibular incisor labial inclination was slightly increased (1-Go-Gn 90 degrees, 1-A-Pg 4 mm) and the overjet (2.5 mm) and overbite (2 mm) corrected.



Figs 14-29a-e Case G.R.: Post-treatment intraoral photographs.



Figs 14-30a-c Case G.R.: Post-treatment radiographs.

The pretreatment balanced profile was maintained with a good nasolabial angle (112 degrees).

Maximum esthetics were maintained during the entire treatment period with the use of the lingual appliance. The active treatment time was 10 months.

Case R.E.

Chief Complaint, Examination Findings, and Diagnosis

A man aged 32 years 10 months complained of a deep bite and differently angulated teeth. At the initial visit, on extraoral examination the patient showed a flat profile with a slightly prominent chin and a skeletal Class I malocclusion. Both the lips were in good position. The frontal view showed a symmetric face and his smile showed maxillary anterior crowding with slight midline deviation (Figs 14-31a and 14-31b). Intraorally he

had a Class II division 2 tendency (molar and canine relationships were Class II), with anterior deep bite and crowding in the maxillary and mandibular arches, as a consequence of bimaxillary incisor retrusion. The overjet was slightly increased (5mm) and the overbite was deep (7mm) in the anterior area. Both the maxillary and mandibular arches were square shaped with anterior dental retrusion (Figs 14-32a to 14-32e).

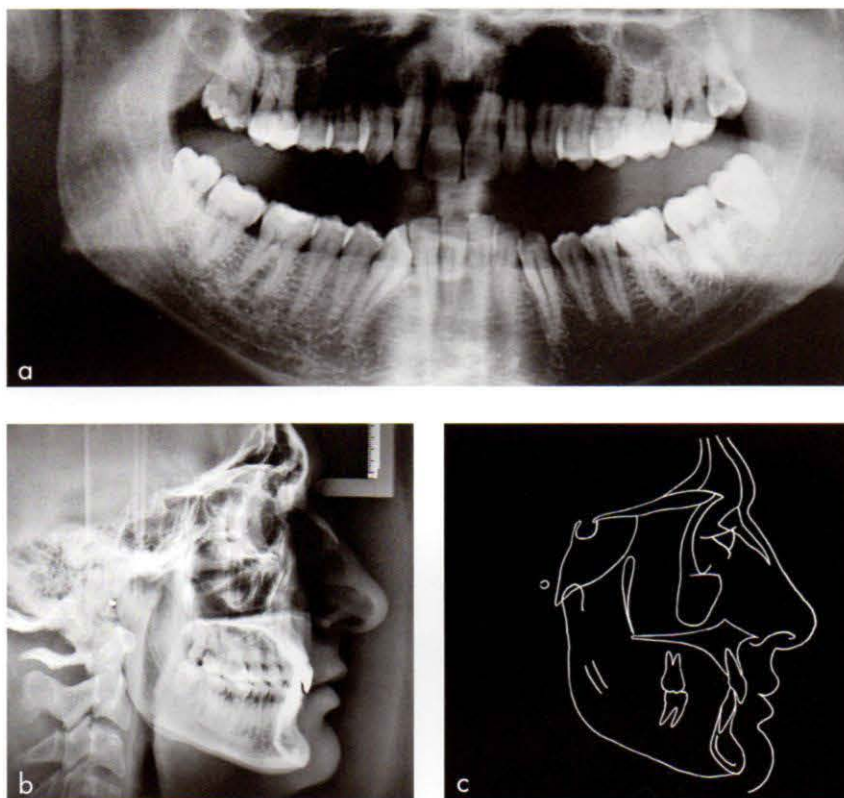
Cephalometric analysis confirmed the skeletal Class I (A-N-Pg -1 degrees) malocclusion with a vertical brachyfacial pattern (S-N/Go-Gn 23 degrees). The dentoskeletal analysis showed lingual inclination of both the maxillary (I/ANS-PNS 103 degrees)



Figs 14-31a,b Case R.E.: Pre-treatment extraoral photographs.



Figs 14-32a-e Case R.E.: Pre-treatment intraoral photographs.



Figs 14-33a-c Case R.E.: Pre-treatment radiographs.

and mandibular incisors (1/Go-Gn 88 degrees, 1/A-Pg 2.5 mm), and consequently, the interincisal angle was increased (152 degrees). Examination of the soft tissues profile revealed an increased nasolabial angle (93 degrees) (Figs 14-33a to 14-33c).

Treatment Plan

- Anterior expansion.
- Alignment and leveling.
- Alignment of maxillary and mandibular midlines with the facial midline.
- Finishing and detailing.
- Post-treatment retention.

Key Treatment Points

- Obtaining good positioning of the maxillary and mandibular incisors.
- Use of STb lingual appliance for the treatment following the patient's request for an esthetic appliance.

Treatment Details

Stage 1

- Maxillary and mandibular STb lingual appliance.
- Maxillary and mandibular aligning and leveling (0.013 copper NiTi archwires) with anterior expansion using crimpable stops (Figs 14-34a and 14-34b).

Stage 2

- Maxillary and mandibular 0.014 NiTi archwires for rotational control (Figs 14-35a and 14-35b).

Stage 3

- Maxillary and mandibular 0.0175 × 0.0175 TMA archwires for torque control.

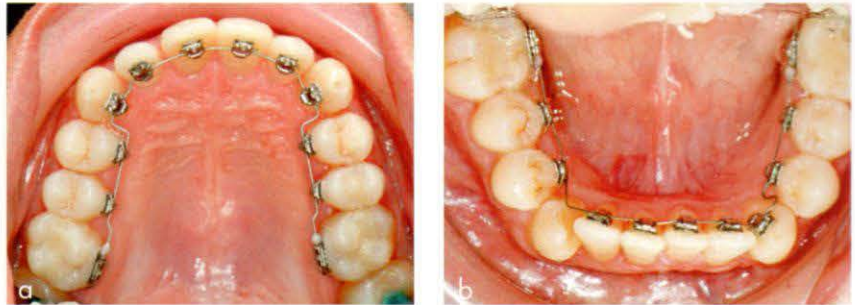
Stage 4

- Maxillary and mandibular 0.016 TMA archwires for finishing and detailing (Figs 14-36a and 14-36b).

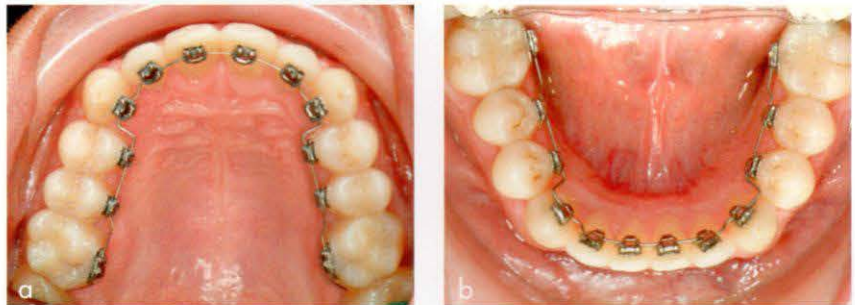
Figs 14-34a,b Aligning and leveling in anterior expansion, using crimpable stops and 0.013 copper NiTi archwires.



Figs 14-35a,b Rotational control with 0.014 NiTi archwires.



Figs 14-36a,b Finishing and detailing with 0.016 TMA archwires.



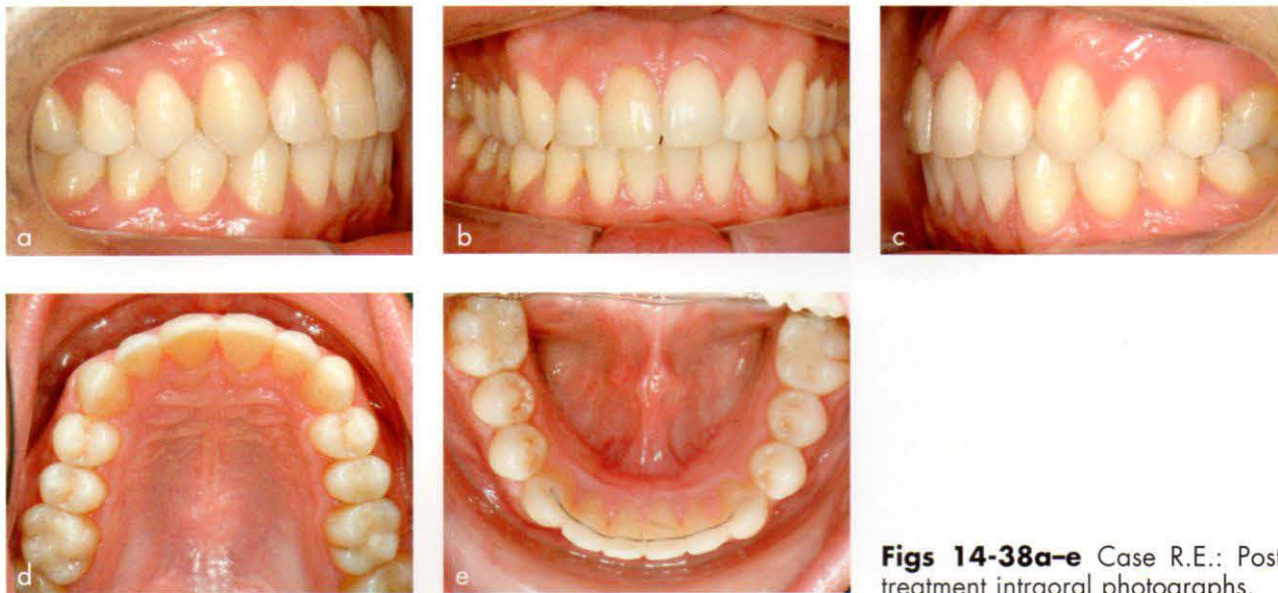
Figs 14-37a,b Case R.E.: Post-treatment extraoral photographs.



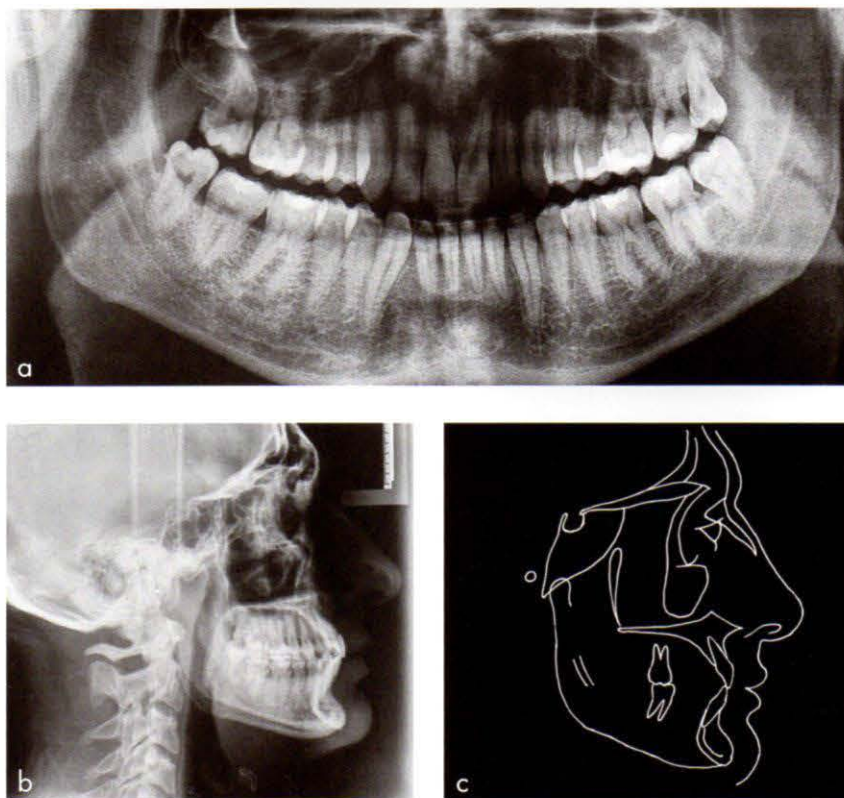
- Debonding and retention with a clear removable retainer in the maxillary arch and a fixed retainer in the mandibular arch.

Post-treatment Analysis

The treatment objectives were fully achieved. The smile was improved and the patient was fully satis-



Figs 14-38a-e Case R.E.: Post-treatment intraoral photographs.



Figs 14-39a-c Case R.E.: Post-treatment radiographs.

fied with the results (Figs 14-37a and 14-37b). Both arches were leveled and aligned with good overjet (2 mm) and overbite (2 mm) (Figs 14-38a to 14-38e). The maxillary incisor inclination was corrected (1/ANS-PNS 112 degrees) and the mandibular incisor labial inclination increased (1/

Go-Gn 95 degrees). The pretreatment balanced profile was maintained with a good nasolabial angle (91 degrees) (Figs 14-39a to 14-39c).

Maximum esthetics were maintained during the entire treatment period with the use of the lingual appliance. The active treatment time was 11 months.

Case P.P.

Chief Complaint, Examination Findings, and Diagnosis

A woman aged 30 years 9 months was referred for esthetic orthodontic treatment with invisible appliance, to improve the functional aspects of her occlusion and both facial and smile esthetics. She had undergone plastic reconstructive surgery on her nose twice previously. At the initial visit, extraoral examination showed a severe skeletal Class III malocclusion with mandibular asymmetry (the mandible was shifted to the right). The profile was flat with a vertical normofacial pattern with a slight brachyfacial tendency. The upper lip was retruded and the lower lip was in a good position. The nasolabial angle was increased owing to previous plastic surgery (Figs 14-40a and 14-40b). The smile revealed an asymmetric occlusion.

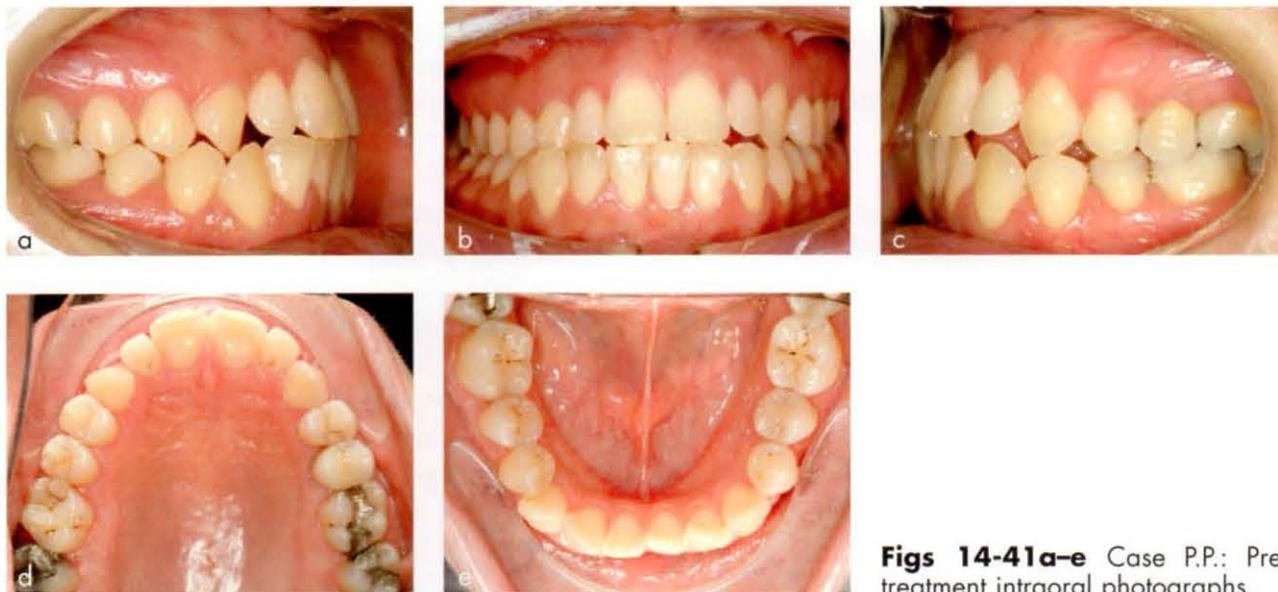
Functional movements showed mandibular deviation on opening, and both incisal guidance and canine guidance were not satisfactory. The patient also referred to past episodes of muscular tenderness and headaches, but without remarkable consequences. In the past few years, the patient did not have pain during jaw movements and on muscle palpation there was no evidence of pain or tenderness.

Intraorally there were no mucogingival problems and the oral hygiene was good. There were restorations in the maxillary and mandibular molars and a prosthetic crown on the maxillary left second premolar. Both maxillary and mandibular third molars were erupted, except the maxillary left third molar, which was impacted. The molars on the right side were in slight Class III relationship, while on the left side both the molars and canines were in a severe Class III relationship. Maxillary and mandibular anterior crowding was present, and the maxillary right lateral incisor and canine were in complete crossbite whereas the maxillary right central incisor and left canine were in an edge-to-edge relationship. The maxillary lateral incisors were diminutive. The patient also had an anterior open bite tendency (overbite 0.5 mm). Compared with the facial midline, the maxillary dental midline was deviated to the left and the mandibular midline to the right. The mandibular arch was asymmetric, with anterior crowding. The maxillary arch was asymmetric and narrow, with a triangular shape and anterior crowding (Figs 14-41a to 14-41e). The dental midlines were not aligned with the facial midline.

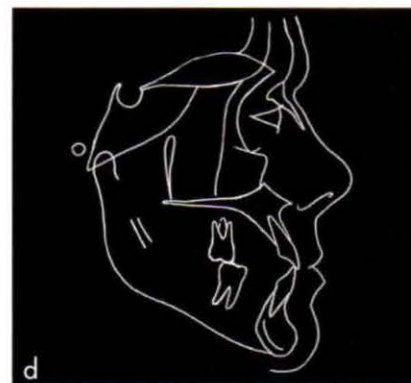
The cephalometric analysis (Fig. 14-42) confirmed the severe skeletal Class III malocclusion (A-N-Pg -4.5 degrees) and a vertical normofacial pattern, with a slight brachyfacial tendency (S-N/Go-Gn 29 degrees). The dentoskeletal analysis showed exces-



Figs 14-40a,b Case P.P.: Pretreatment extraoral photographs.



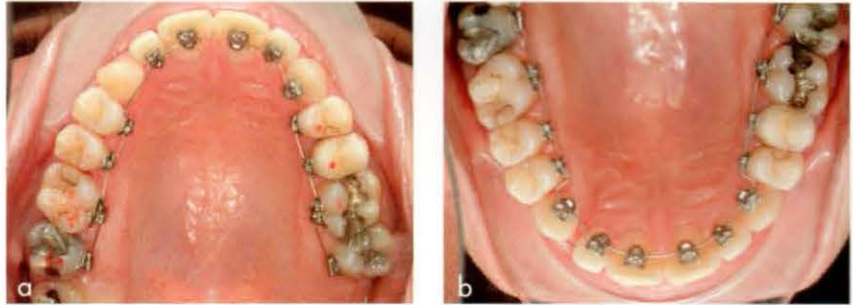
Figs 14-41a-e Case P.P.: Pretreatment intraoral photographs.



Figs 14-42a-d Case P.P.: Pretreatment radiographs.

sive labial inclination of the maxillary incisors (1/A-Pg 120 degrees) while the mandibular incisors were slightly protruded (1/A-Pg 4 mm). As a consequence, the interincisal angle was reduced (125 degrees). Analysis of the soft tissues profile revealed

an increased nasolabial angle (120 degrees). With reference to Ricketts' E line, the upper lip was retruded (-7 mm) while the lower lip position was normal (-3 mm). The posteroanterior cephalometric analysis confirmed the severe mandibular asymmetry.



Figs 14-43a,b Aligning and leveling of the maxillary arch with 0.012 NiTi and 0.016 TMA archwires.

Treatment Plan

As there was no evidence of muscular or temporomandibular joint problems (no pain or clicking) based on the history and clinical examination, orthodontic-orthognathic treatment was planned.

- Extraction of both maxillary and mandibular third molars.
- Alignment of the dental arches.
- Orthodontic preparation and coordination of the maxillary and mandibular arches.
- Reduction of maxillary and mandibular incisors protrusion.
- Surgical correction of the skeletal malocclusion, in both the sagittal and transverse planes.
- Post-surgical orthodontic finishing and detailing.
- Post-treatment retention.

Key Treatment Points

- Correction of the severe skeletal malocclusion and face asymmetry with combined orthodontic-orthognathic treatment.
- Use of STb lingual appliance for the treatment following the patient's request for an esthetic appliance.

Treatment Details

Stage 1

- Extraction of the maxillary and mandibular third molars.
- Maxillary and mandibular STb lingual appliance.
- Maxillary alignment and leveling (0.012 NiTi and 0.016 TMA archwires) (Figs 14-43a and 14-43b)

- Mandibular alignment and leveling (0.012 NiTi and 0.016 TMA archwires) with slight anterior stripping (Figs 14-44a to 14-44c).

Stage 2

- Maxillary and mandibular 0.0175 × 0.0175 TMA for establishment of the torque (Figs 14-45a to Figs 14-45b).

Stage 3

- Maxillary and mandibular 0.017 × 0.025 stainless steel for arch coordination (Figs 14-46a to 14-46d).

Stage 4

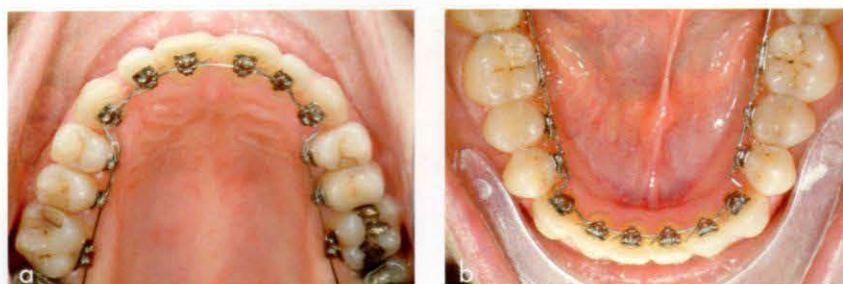
- Surgical correction of the malocclusion and face asymmetry.
- Maxillary osteotomy (Le Fort) with transverse expansion and sagittal advancement.
- Mandibular bilateral sagittal osteotomy with correction of the asymmetry and skeletal malocclusion – the maxillofacial surgeon reported it was not possible to correct the nasal profile because the nose did not have enough cartilaginous support, owing to previous plastic surgery.
- Post-surgery recovery.

Stage 5

- Maxillary and mandibular 0.016 TMA archwires with up and down elastics for orthodontic finishing and detailing (Figs 14-47a and 14-47b).
- Debonding and retention with a clear removable retainer in the maxillary arch and a fixed retainer in the mandibular arch.



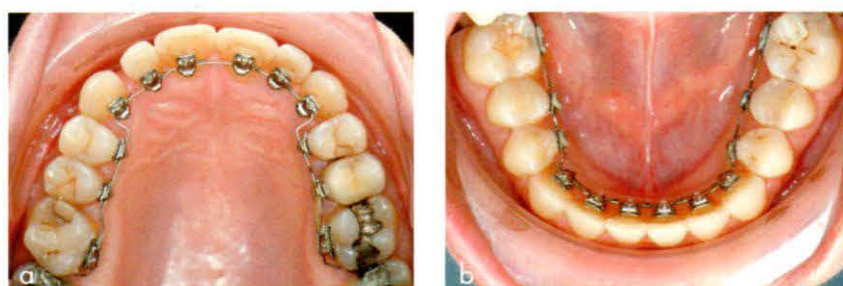
Figs 14-44a-c Aligning and leveling of the mandibular arch with 0.012 NiTi and 0.016 TMA archwires and slight anterior stripping.



Figs 14-45a,b Establishment of the torque with 0.0175 x 0.0175 TMA archwires.

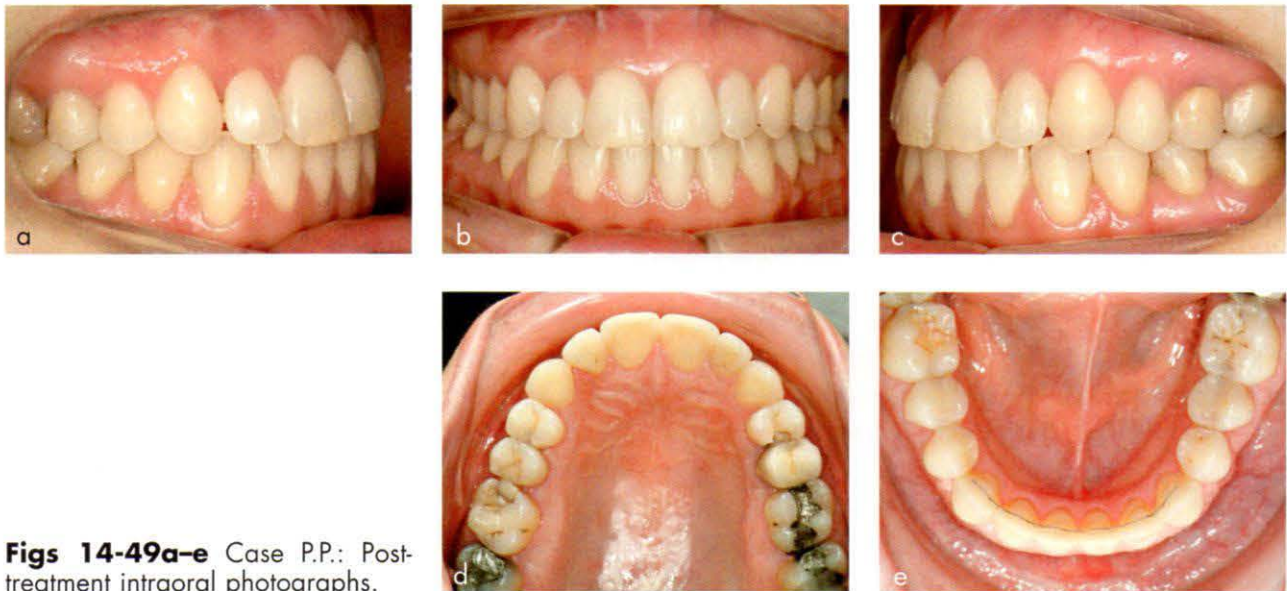


Figs 14-46a-d Arch coordination with 0.017 x 0.025 stainless steel archwires.



Figs 14-47a,b Finishing and detailing with up and down elastics and 0.016 TMA archwires.

Figs 14-48a,b Case P.P.: Post-treatment extraoral photographs.



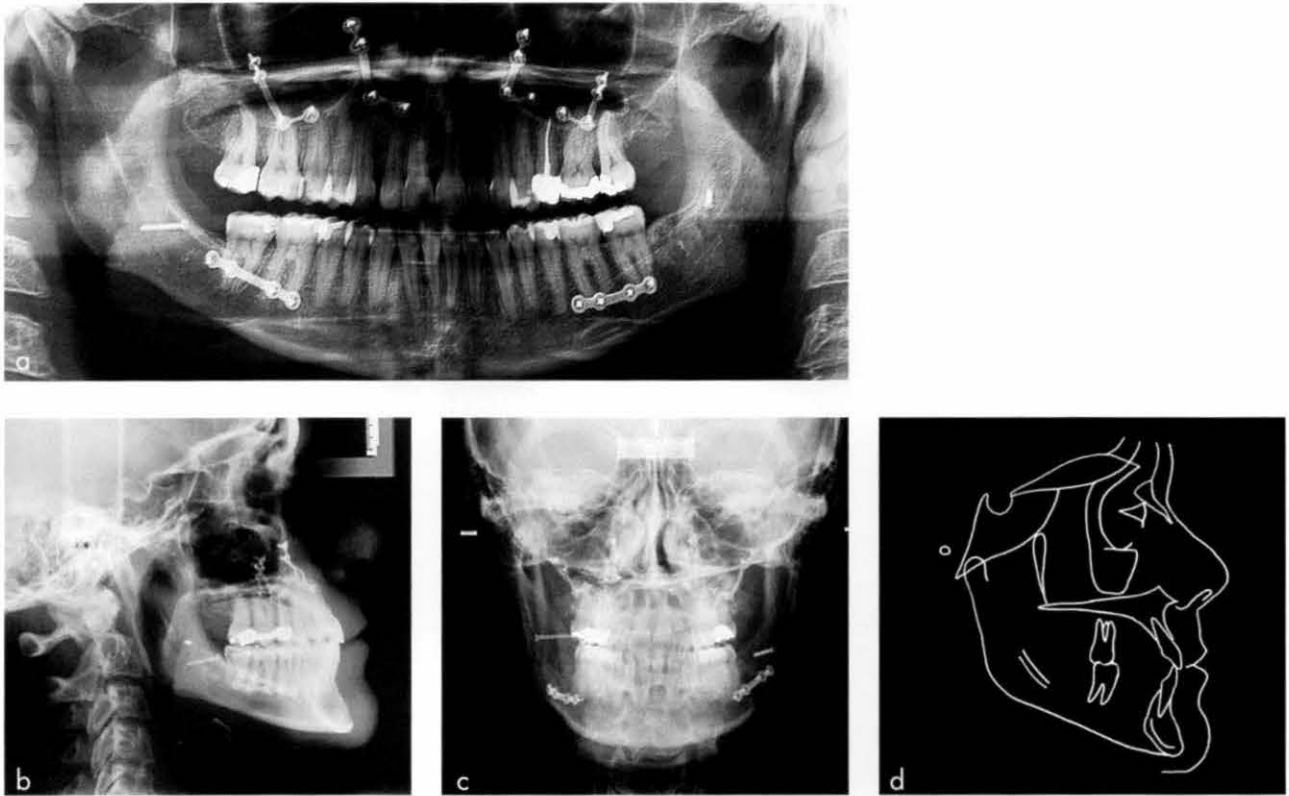
Figs 14-49a-e Case P.P.: Post-treatment intraoral photographs.

Post-treatment Analysis

The treatment objectives were fully achieved. The severe skeletal Class III malocclusion was reduced and corrected to a Class I. Facial balance and profile was significantly improved, even without rhinoplasty. The esthetics of the smile were also greatly improved and the patient was fully satisfied with the results. Mouth opening was within the normal range and mandibular functional movements also appeared to be in the normal limits. No signs or symptoms of temporomandibular joint or muscular problems were present. On frontal view, the symmetric face could be appreciated, with clear evidence

of correction of the skeletal problem (Figs 14-48a and 14-48b).

The severe dental Class III relationship (on the left side) was corrected to bilateral full molar and canine Class I relationship and maxillary and mandibular incisor inclination was improved to a good position. Both arches were symmetric, leveled and aligned with a good overjet and overbite, and crossbite was corrected. The occlusal intercuspation was greatly improved, with good canine and incisal guidance. The anterior open bite tendency was corrected and the dental and facial midlines were coincident (Figs 14-49a to 14-49e).



Figs 14-50a-d Case P.P.: Post-treatment radiographs.

Cephalometrically, the sagittal skeletal relationship was improved (A-N-Pg -1 degrees), and the vertical relationship was not changed (S-N/Go-Gn 29 degrees). Maxillary and mandibular incisors dental protrusion was reduced (1/ANS-PNS 116 degrees, 1/Go-Gn 87 degrees), and mandibular incisors were in good position (1/A-Pg 2 mm). The interincisal angle was improved (133 degrees) and optimal overjet (2 mm) and overbite (2 mm) were established. Regarding the soft tissue esthetics, the nasolabial angle (116 degrees) and the upper lip position (-5 mm) were improved. The posteroanterior cephalometric radiograph

showed good skeletal symmetry (Figs 14-50a to 14-50d).

Maximum esthetics were maintained during the entire treatment period, with the use of the lingual appliance. A fixed lingual retainer was bonded on the mandibular arch to prevent relapse of anterior crowding and rotations. A clear removable retainer was constructed for the maxillary arch to make maintenance of hygiene easier. The active treatment time was 18 months. The patient also underwent other dental cosmetic treatments, such as restoration of the maxillary right lateral incisor to improve its shape, and bleaching.

15 STB SOCIAL 6: ESTHETIC TREATMENT FOR TODAY'S DEMANDING PATIENT

Introduction

In this modern era, characterized by changing personal relationships and social networking, the image one presents has become important. As a consequence, orthodontic patients have high esthetic demands. Whenever we are asked to identify the significant changes that we have seen in orthodontics in the past few years, we always include the major role that patient choice now has in treatment selection.

Thanks to the internet and direct-to-consumer marketing, patients are armed with more information about treatment than ever before. Most patients come to us mainly wishing to improve their smile and they want this done as fast as possible. Today, multiple alternative esthetic treatments are available, and patients want to compare the alternatives available to them before deciding on which treatment will deliver the fastest, most comfortable and most discreet smile transformation. The STb "Social 6" Light Lingual System was developed for esthetically demanding patients in need of minor to moderate corrections in the anterior dental arch segments. STb "Social 6" presents a further breakthrough in lingual technology – originally advanced by the STb Light Lingual System – and is a remarkably simple orthodontic treatment technique for clinicians to learn and master. STb "Social 6" is the most esthetic treatment option available on the market today, offering patients and clinicians unprecedented comfort, speed of treatment, invisibility, and consistently high-quality results.

The Changing Dynamics of the Doctor–Patient Relationship

In the early days of lingual orthodontics – prior to the advent of aligners, ceramic braces and other esthetic options – a patient's motivation for invisible treatment meant that they were willing to accept the all-too-common side effects of lingual treatment: discomfort, tongue pain, mastication and speech problems, and gingival inflammation. Patients were even willing to accept longer treatment time and higher costs compared with conventional labial treatment. This is no longer the case. With the increasing ease of accessing treatment information, and availability of aligners, clear braces and even veneers, and the growing involvement of general dental practitioners in orthodontics and esthetic dentistry, patients want treatment that is fast, not easily noticeable, comfortable, and requiring minimal compliance.

At present, the perception of dental appearance, both in one's own self and in relation to other people, is of major importance in orthodontics and we should place emphasis on the improvement of dental esthetics in our orthodontic treatment planning to enhance the general well-being of our patients. The psychological benefit of the treatment often prevails over improvement in function and dental health. As has been demonstrated by several studies, anterior teeth are of primary importance for patients as part of their self-perception of dental appearance. This is influenced by social esthetics norms and also psychological factors and personal norms of dental attractiveness. Other dental issues, such as discoloration and morphological crown defects, may also influence the level of satisfaction, especially in adult patients. Therefore patients are more aware

of, and interested in getting treatment for, spacing, crowding, and rotations of the anterior teeth rather than an excessive overjet or interocclusal problems (Espeland and Stenvik 1991).

Abei and co-workers (2004) used the ABO Index to evaluate patients' perception of orthodontic results when treatment was provided by specialists and general dentists. They found that differences in the patients' perceptions were not statistically significant. While clinicians base the evaluation of treatment outcome on factors that include facial balance, function, dental health, and overall smile esthetics, patients were essentially concerned about having straight anterior teeth. This is an important point for orthodontists to keep in mind in today's patient-driven treatment environment.

"Social 6" Treatment: Just an Esthetic Problem?

The position of the anterior teeth has an important role in determining the contour and shape of the marginal and interdental gingivae and also the alveolar bone morphology. According to Diedrich (2000), the periodontal relevance of anterior crowding has three main aspects:

- oral hygiene
- morphology of the gingiva, interdental septum, and the alveolar bone in relation to the crowding
- periodontal therapy.

Although there is no evidence in the literature about the pathogenetic effects of anterior crowding, relevant studies published in the past 30 years seem to show a positive correlation between anterior crowding and plaque retention.

Regarding the periodontal structures, crowding can cause compression of the papillae and result in reduced connective tissue between the epithelial margins. With regard to the alveolar structure, crowding can result in reduced cancellous bone and vascularization with the risk of bony fenestration.

Maintenance of oral hygiene in the presence of crowding is more complicated both for the patient and the doctor during routine oral hygiene procedures such as flossing, scaling and root planing.

"Social 6" treatment can not only provide an esthetic advantage to the patient but it also tends to improve their oral hygiene and the gingival and bone morphology.

A Better Way to Treat Minor Malocclusions

Clinical experience shows that there are many orthodontic cases that are not characterized by severe crowding requiring extraction treatment or skeletal malocclusions requiring a surgical resolution. Owing to the type of skeletal pattern found among the Caucasian populations, compared with Asian populations, most malocclusions in Caucasian patients can be treated by non-extraction treatment.

Some patients, specially those who ask for esthetic treatment, have mild to moderate crowding in the anterior segment(s), depending on the dental-skeletal discrepancy and the presence of bimaxillary retrusion. If patients do not have problems with occlusion in the molar areas and/or do not have functional problems, or are wearing fixed/removable prosthetics in the posterior area, esthetic treatment of the anterior teeth could be the solution to their problem.

The name STb "Social 6" derives from the **social** context in which the treatment is to be carried out and the **six** anterior teeth involved in the treatment.

The STb "Social 6" is a highly efficient and effective application of lingual treatment based on the use of small brackets and an advanced philosophy of simplified procedures, light forces, and low-friction mechanics. Thus STb "Social 6" is a superior way to treat simple malocclusions – relapsed cases, minor tooth movement, rotations, gaps or crowding of the anterior teeth – especially when compared with other esthetic treatment options such as aligners and veneers. STb "Social 6" addresses the patient's need for straight anterior teeth and the clinician's

need for maximum three-dimensional control of the treatment process.

Although currently many patients with mild to moderate anterior malocclusions are treated with aligners, and this is a viable option for certain patients, in many instances aligners do not produce anticipated results. They require uninterrupted patient compliance for treatment periods ranging from 1 to 2 years and must be worn at least 20 hours a day. From the purely esthetic viewpoint, aligners are a less noticeable appliance than traditional braces but are not the truly invisible treatment that lingual orthodontics is. STb "Social 6" does not require patient compliance and costs much less than treatment with aligners.

Clinicians may use STb "Social 6" to treat any case of minor to moderate crowding or spacing with maximum control without worrying about misplaced aligners or lapses in wearing time. As a result, they can confidently predict treatment time and deliver optimal results.

Features of the STb "Social 6" Treatment

Quality

STb "Social 6" treatment can be used with many advantages both for patients and orthodontists, as a simplified lingual technique, extremely comfortable, very fast and, above all, totally predictable and reliable with regard to the quality of the treatment results.

Treatment with STb helps address one of the problems common to anterior crowding – gingival recession – especially in relation to rotated teeth. Gingival recession is not only an esthetic problem, but is also important from a periodontal standpoint, as it affects oral hygiene/plaque retention and modifies the topography of the gingiva, interdental septum and the alveolar bone. These periodontal issues can make corrective therapy such as scaling, root planing, or periodontal regenerative approaches difficult.

Conversely, the positive periodontal effects of correcting anterior crowding translate into better

oral hygiene, simplified surgical therapy, and more favorable conditions for periodontal regeneration.

Speed

The STb "Social 6" technique utilizes a passive ligation bracket design and light high-tech wires that markedly reduce friction and accelerate treatment. STb uses continuous light forces (25 to 30 g) and is biologically compatible. Treatment can be completed in as little as 5 weeks and rarely carries on beyond 4 months. The combination of low-friction bracket design and light wire forces maximizes the sliding of the archwire in the bracket slot using an 0.013 copper nickel titanium (CuNiTi) wire.

Comfort

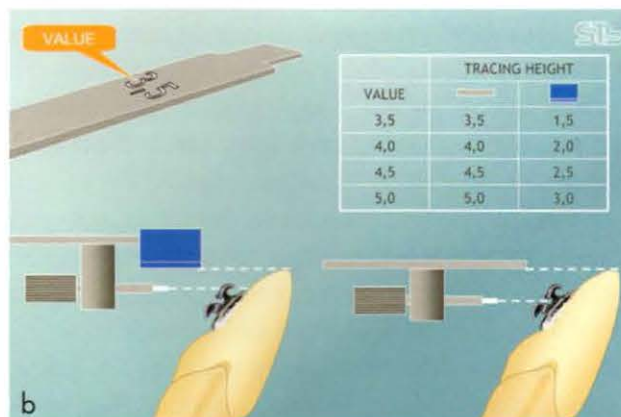
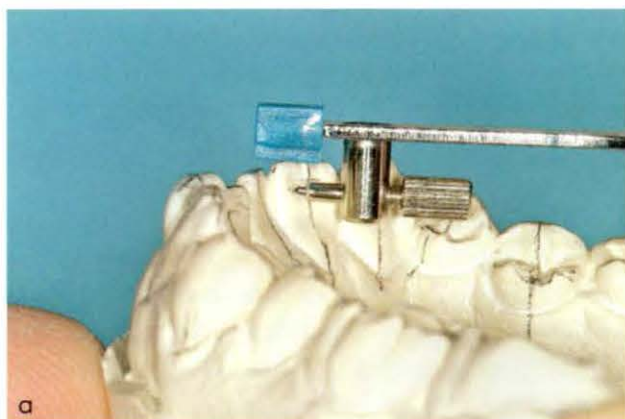
The STb "Social 6" low-profile brackets (just 1.5 mm) provide several advantages for patients. The STb bracket has a thin and rounded contour that eliminates (or at least greatly reduces) tongue discomfort, and the speech and mastication problems that plagued patients treated with older lingual technology. If there are speech difficulties, they disappear a few days after bonding. Improved bracket design has also made oral hygiene much easier for patients and gingival inflammation rarely occurs.

Simplicity

STb "Social 6" is remarkably easy to learn and master for orthodontists new to lingual technology. STb "Social 6" features a simple two-archwire sequence in which teeth quickly unravel and align (most cases require just one archwire).

Efficient Light-force Mechanics

A number of design improvements to the original STb appliance have made it possible to achieve optimal treatment outcomes with light forces and low friction. As a result, treatment times are shorter compared with other lingual techniques, and the same efficiency standards can be achieved as the most effective labial treatments.



Figs 15-1a,b Mark the bracket height.

- The 1.5 mm bracket profile greatly reduces occlusal interference and the small base bonds well to the tooth surface, with a negligible rate of bracket failure.
- The anterior brackets sit firmly on the flat surface of the teeth close to the incisal edge, so the archwire runs close to the tooth surface.
- The narrow width of the brackets considerably increases the inter-bracket distance, enhancing archwire flexibility and working range, while lowering the forces applied to the teeth.
- Ligation requires only one conventional ligature tie, with no need for double overties, reducing chair-side time.
- There is no need for customized archwire bending and no need for resin composite buttons.

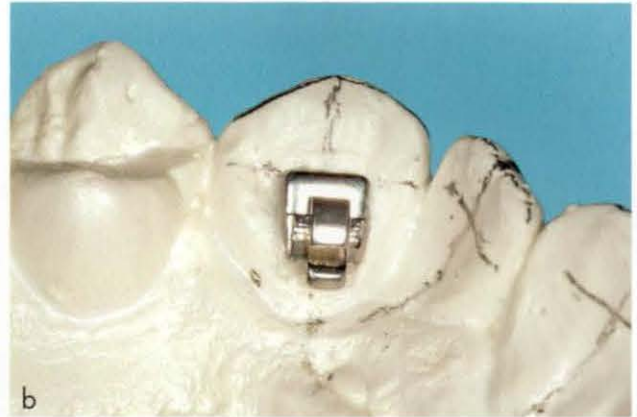
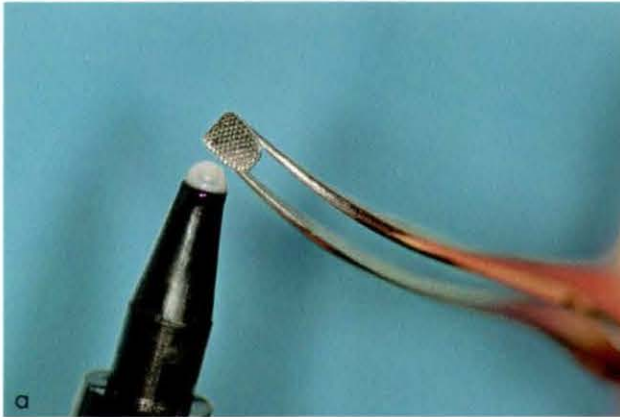
The Simplified "Social 6" Laboratory Procedure

When using the simplified laboratory procedure for "Social 6" cases, it is not necessary to use an outside laboratory setup in patients who will not require anterior torque control. The simplified laboratory procedure can be managed in the office and in most cases does not require full Torque Angulation Reference Guide (TARG) or Custom Lingual Appliance Setup Service (CLASS) set-up, making it quick, simple, low cost, and more reliable, as the clinician can control directly the laboratory steps.

Step-by-step Laboratory Procedure

Bracket Positioning

1. Use high-quality stone models, and ensure there are no air bubbles or chips or excess stone on the lingual surfaces of the teeth.
2. Cover the model with a separating medium.
3. Trace with a fine pencil (0.5 mm) the edges of the anterior teeth, and the occlusal, labial, and lingual margins of the premolars and molars. Draw the long axis of the teeth on both the labial and lingual sides extending 5 mm apically, paying close attention to rotations, inclinations and morphologic alterations.
4. Using a bracket gauge positioner (ORMCO, USA) draw a horizontal line of reference at 3.5 to 4 mm from the incisal edges of the maxillary incisors, and 3.5 mm from the incisal edges of the mandibular incisors. On the canines the reference lines should be positioned 0.5 to 1 mm nearer to the gingival margin compared with the incisors (Figs 15-1a and 15-1b).
5. Apply the resin composite to the bracket base (Fig. 15-2a) and position the occlusal margin of the base of the bracket against the reference line drawn on the tooth, adjusting the position according to the angulation or adding overcorrection if necessary (Figs 15-2b and 15-2c). Remove any excess resin composite and light cure each tooth for 20 seconds.



Figs 15-2a-c Set the brackets on the stone model.

Archwire Preparation

1. Place an 0.013 CuNiTi "Social 6" preformed archwire (Fig. 15-3) into the bracket slots and mark the inter-incisal point and two other points 2 to 3 mm distal to the canines (Figs 15-4a to 15-4c).
2. Make two 90 degree bends in the archwire at the points marked distal to the canines (Fig. 15-5) and cut the wire, leaving 1 mm of wire distal to the bends on each side (Fig. 15-6).
3. Apply a small amount of flowable resin composite on the distal ends of the archwire to form small composite balls at the wire ends. This makes it comfortable for the patient and prevents the sectional archwire from sliding in the brackets slot (Figs 15-7a and 15-7b).

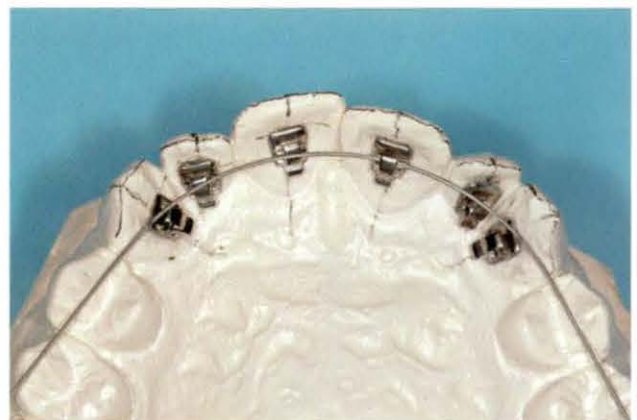
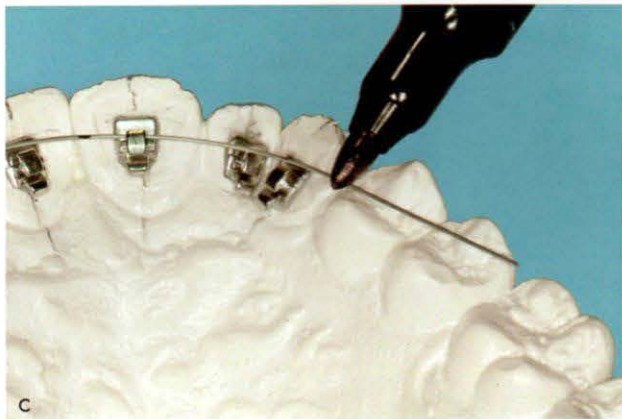


Fig. 15-3 "Social 6" preformed 0.013 CuNiTi archwire.



Figs 15-4a-c Mark the reference points on the archwire.

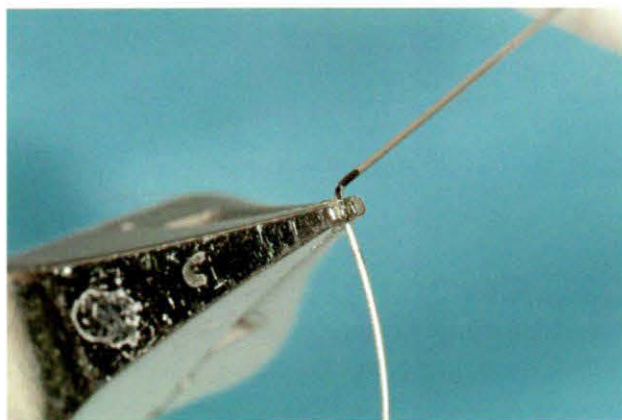


Fig. 15-5 Bend the archwire 90 degrees at the distal markings.

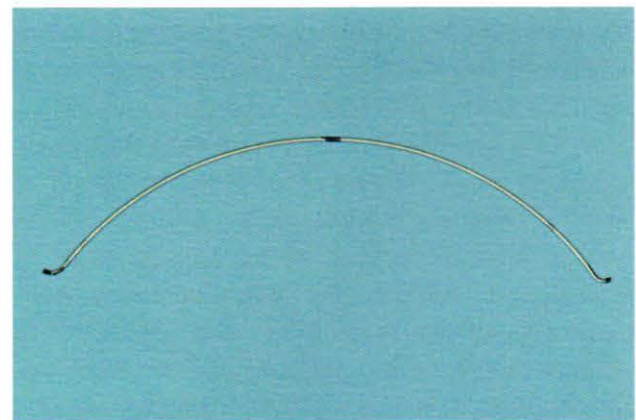
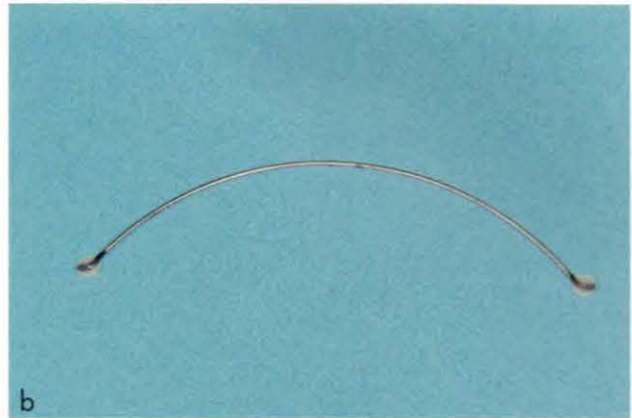
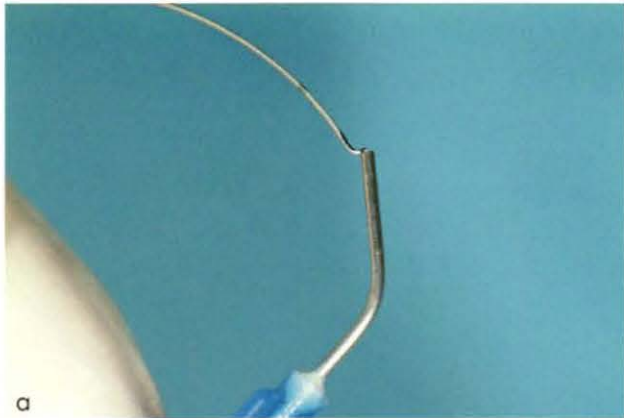


Fig. 15-6 Cut the archwire 1 mm distal to the bends.



Figs 15-7a,b Add small balls of flowable resin composite distally.

Making the Transfer Tray

1. Using a thermo glue gun (Fig. 15-8) make the transfer tray, completely covering the brackets on the lingual surfaces and extending the tray to the labial surface for 2 to 3 mm (Figs 15-9a and 15-9b).
2. Place the model with the tray in cold water for around 10 minutes, to allow the separating medium to dissolve. This makes it easier to remove the tray from the model.



Fig. 15-8 A glue gun.



Figs 15-9a,b Make the transfer tray.



Fig. 15-10 Enamel etching.



Fig. 15-11 Rinsing and drying.



Fig. 15-12a Apply a thin layer of OrthoSolo universal bond enhancer.



Fig. 15-12b OrthoSolo (ORMCO).

Clinical Bonding Procedure

Bracket Bonding

Clean the bracket bases with acetone, methylated spirits, or a micro sandblaster – this cleans any excess separating medium. Be careful not to remove the composite that is on the bracket base.

1. Carry out routine oral hygiene procedures.
2. Apply orthophosphoric acid to the enamel for 30 seconds (Fig. 15-10).
3. Rinse each tooth surface with air/water spray for at least 5 seconds.
4. Dry all the teeth (Fig. 15-11).

5. Apply a thin coat of OrthoSolo on the surface of each tooth. Do not cure it (Figs 15-12a and 15-12b).
6. Paint each bracket base with OrthoSolo. Again do not cure it.
7. Apply a small amount of flowable composite on each bracket base (Figs 15-13a and 15-13b).
8. Seat the transfer tray on the teeth and light cure each tooth from the labial surface for 30 seconds (Fig. 15-14).
9. The patient should then rinse with hot water (40 to 45 degrees) for 30 seconds – this helps to soften the transfer tray for easy removal.



Figs 15-13a,b Apply a thin layer of flowable composite on bracket bases (Flow Tain LV, Reliance Orthodontics Product, USA)



Fig. 15-14 Sit the tray on the teeth and cure.



Fig. 15-15 Remove the transfer tray easily.

10. Remove the tray starting from its right or left edge, using a rotating movement in a lateral direction (Fig. 15-15).
11. Any excess composite on the teeth should be removed using a fine round bur.
12. Check that there is no resin composite remaining in the interdental spaces, by using a matrix strip or dental floss (Fig. 15-16).



Fig. 15-16 Gently use an interproximal strip to remove composite excess to reduce friction.



Fig. 15-17 Place an 0.013 CuNiTi sectional arch and ligate with metal ligatures (0.008).

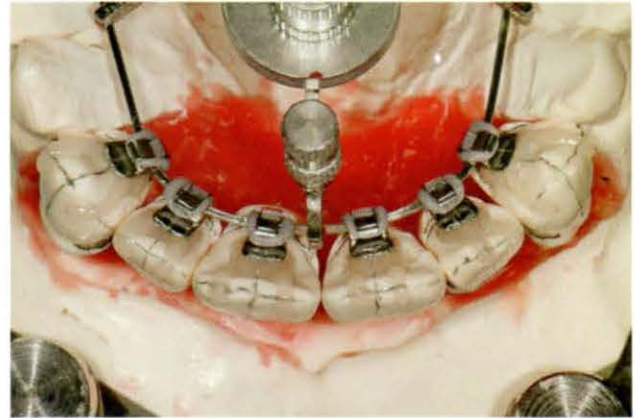


Fig. 15-18 Laboratory set-up procedure for social six cases when torque control is required

Archwire Sequence and Ligation

STb "Social 6" treatment features a simple two/three-wire sequence; teeth quickly unravel and align. Most of the treatment is carried out with just a round archwire, usually a low-force NiTi or CuNiTi wire.

1. Place a 0.013 CuNiTi wire during the initial leveling and alignment phase.
2. Place a 0.016 NiTi or 0.016 titanium molybdenum alloy (TMA) archwire for additional alignment (rotation control) and finishing if needed.
3. Tie the archwire to the brackets using 0.008 steel ligatures to maximize the STb low-friction effect (Fig. 15-17); after leveling 0.110 or 0.120 elastic ligatures can also be used. No double overtie is required.
4. Check the archwire for distortion during the recall visits (5 to 6 week intervals) and replace as needed.

Optional 0.017 × 0.017 CuNiTi or 0.017 × 0.017 TMA archwires can be used for torque control of an individual tooth. If torque control of more than one tooth is required, it is advisable to use a laboratory set-up procedure (Fig. 15-18).

The working time for all these archwires is approximately 4 to 6 months, which is the maximum treatment time for most of STb "Social 6" cases.

Indications

- Relapsed cases
- Angle Class I malocclusion with slight maxillary crowding
- Angle Class I malocclusion with slight mandibular crowding
- Angle Class I malocclusion with slight crowding and triangular-shaped teeth
- Angle Class II malocclusion with no dysfunctional problem in adult patient with anterior crowding
- Angle Class I malocclusion with mandibular crowding and cone-shaped maxillary teeth
- Angle Class I malocclusion with mandibular crowding and large mandibular central incisors
- Diastema closure: maxillary and/or mandibular.

Clinical Considerations

The resolution of anterior crowding often requires progressive interdental stripping throughout the treatment. The mesiodistal diameter of the mandibular lateral incisors is significantly larger than that of the mandibular central incisors, thus more reduction of the laterals is needed (see Fig. 15-16). The situation is similar with the maxillary and/or mandibular first premolars, thus it may be necessary to do more stripping of these teeth than of the second premolars.

Illustrative STb "Social 6" cases

Case 1: Crowding lower arch, STb "Social 6" treatment with stripping. Treatment time 4 months.



Fig. 15-19 Case 1: Pretreatment (a), 0.012 NiTi archwire (b,c), 0.016 TMA archwire for detailing (d), Posttreatment (e).

Case 2: Crowding upper arch, STb "Social 6" treatment with stripping. Treatment time 6 months.

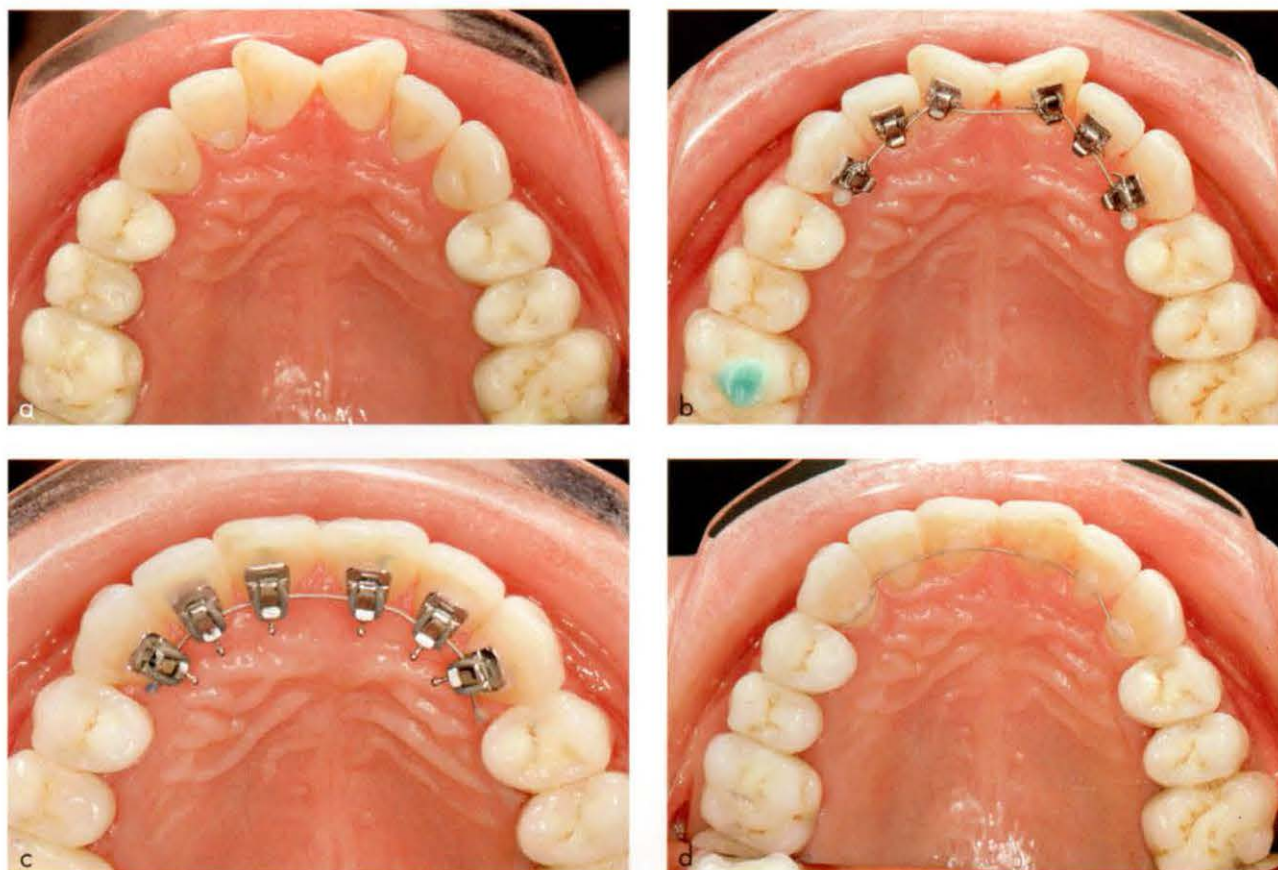


Fig. 15-20 Case 2: Pretreatment (a), 0.013 Copper NiTi archwire (b), 0.016 TMA archwire for detailing (c), Posttreatment (d).

It is also necessary to incorporate the appropriate anterior arch form into the archwires to avoid excessive inter-canine expansion, or it is advisable to use the preformed "Social 6" archwires.

Owing to the biomechanical characteristics of the lingual technique, the "Social 6" treatment does not result in labial inclination of the maxillary and mandibular incisors, as a side effect.

Posterior build-ups can be used, especially in patients with deep bites, preferably on the maxil-

lary second molars, to balance premature contact between the mandibular incisors and the maxillary brackets (occlusal trauma) and for patient comfort. The build-ups should be ground gradually during treatment (2 to 3 months), to re-establish the occlusal posterior contacts following incisor intrusion.

As mentioned in the previous section, in patients in whom torque control of one or more teeth is necessary, it is preferable to use a laboratory set-up procedure for bracket positioning.

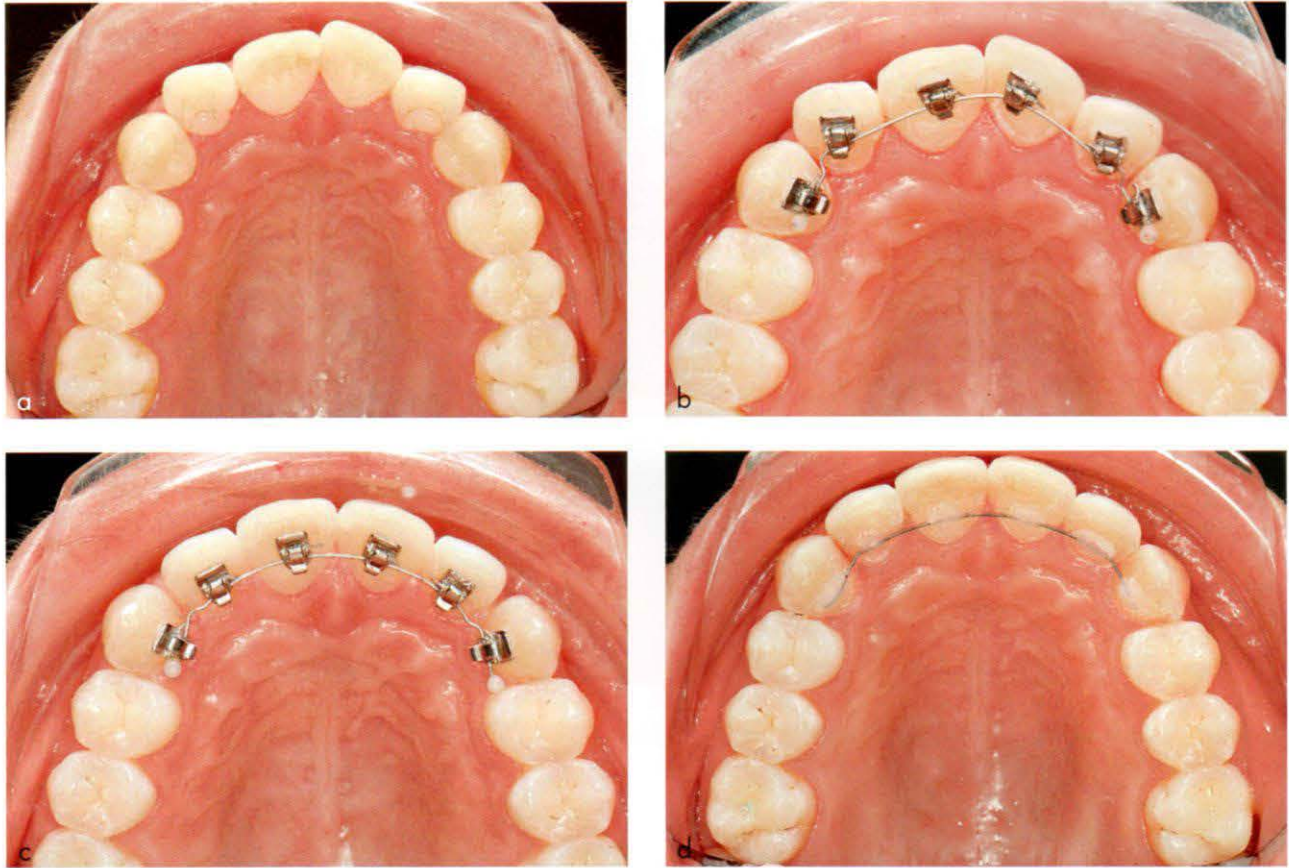
Case 3: Crowding upper arch, STb "Social 6" treatment. Treatment time 5 months.

Fig. 15-21 Case 3: Pretreatment (a), 0.013 Copper NiTi archwire (b), 0.016 TMA archwire for detailing (c), Posttreatment (d).

Conclusion

The demand for esthetic orthodontics is continuing to grow as "self-empowered" patients look for fast, invisible and discreet treatments to improve their smile. The STb "Social 6" Light Lingual System provides the orthodontist with an efficient treatment modality with maximum control of the treatment process. It delivers a totally discreet, fast and comfortable treatment that meets the

treatment expectations of today's demanding patient. STb "Social 6" is easy to learn for new lingual clinicians, and it will treat most patients with minor to moderate anterior malocclusions in 2 to 4 months. Embracing STb "Social 6" could be a first step to incorporating lingual orthodontics in your daily practice to treat both anterior and full-arch cases.

16 LINGUAL STRAIGHT WIRE METHOD

Introduction

The lingual orthodontic technique Dr. Fujita introduced in the 1970s has mainly utilized a mushroom-shaped arch form because of the morphology of the lingual surface of the teeth. However, this method has several disadvantages, including complicated wire bending that prolongs the chair-side time and can also affect the treatment result, and difficulty in upper and lower arch coordination.

To simplify the mechanics, Dr. Takemoto and Dr. Scuzzo developed the lingual straight wire (LSW) method in 1995. However, the early LSW method of the 1990s (Fig. 16-1) also had several problems, such as use of thick brackets that pressed onto the gingiva, caused general patient discomfort and were associated with short inter-bracket spans. The new LSW method was developed to overcome these faults.

Why Use the Lingual Straight Wire Method?

As mentioned above, while using mushroom-shaped archwires, wire bending with vertical steps and in-out bends between the canines and first bicuspid is needed in most cases, and the result is highly dependent on the shape of the finishing archwire. The new LSW method (Fig. 16-2), with its plain arch form makes arch coordination easier, and simple biomechanics such as sliding mechanics can also be used. Moreover, simpler mechanics and less wire bending reduce the technique-related differences between different clinicians and also reduce chair-side time. The patient's level of comfort is also improved.

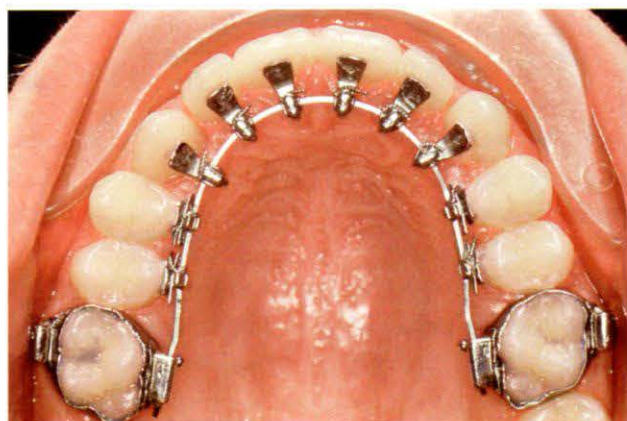


Fig. 16-1 An example of the lingual straight wire technique developed by Dr. Takemoto and Dr. Scuzzo in the 1990s.

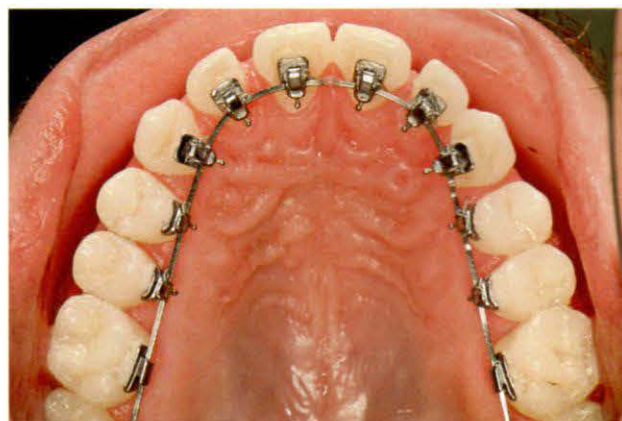


Fig. 16-2 An example of the new lingual straight wire method.

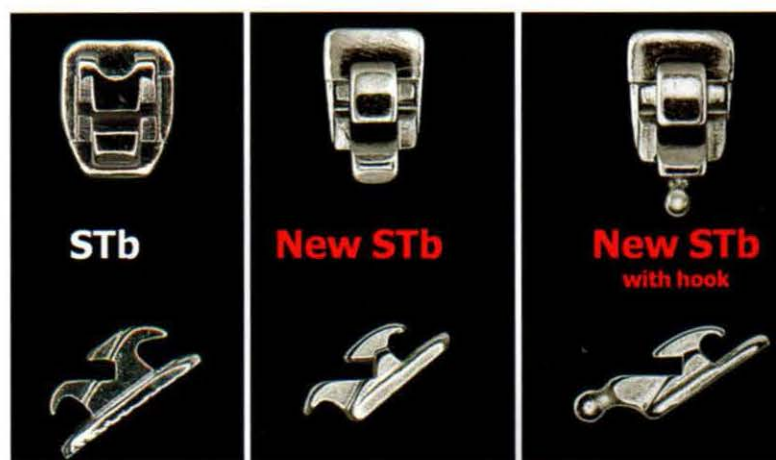


Fig. 16-3 Comparison of old and new versions of the STb bracket.



Fig. 16-4 Passive ligation steps (0.3 mm) are provided on both the mesial and distal sides of the new STb bracket.

New STb Designs

The STb appliance system was developed in 2003, based on three factors: more comfortable for the patient, shorter chair-side times, and greater technical reliability. In the LSV method, the bracket position needs to be much closer to the gingival margin and lingual surface of the tooth. Therefore, the original STb bracket design was modified, and in 2009 the new STb bracket with gingival offsets and hooks was developed (ORMCO, USA) (Fig. 16-3).

The new STb bracket has a milled 0.018×0.025 horizontal slot made of a 17-4PH stainless

steel, whereas the bonding pad material is 316L stainless steel. The slot width has been reduced to increase the inter-bracket distance. This modification has further reduced both the force exerted by the archwire and the resistance to sliding mechanics. To increase the inter-bracket distance, it is also important to bond the brackets much closer to the lingual tooth surface, as the force is inversely proportional to the cube of the inter-bracket distance.

Moreover, to move a tooth with a low-friction system, conventional STb and the new STb brackets have a "passive ligation step" (0.3 mm; extensions of the bracket slot base) on both the mesial and the distal sides of the bracket slot. These passive ligation steps on the sides of the bracket prevent the ligature from binding the archwire against the slot base and thus reduce friction when using an 0.012 or 0.013 archwire (Fig. 16-4). Furthermore, this new bracket morphology allows easier ligation with the incorporation of the gingival hook, with metal or elastic ligatures, and therefore reduction in chair-side time in comparison with conventional lingual appliances.

The new gingival offset slot position reduces the in-out thickness, allowing the anterior brackets to be bonded closer to the lingual surface, and thus reducing the composite bonding material thickness on the bonding pad, bonding failure, the build-up dimensions, and patient discomfort, as well as avoiding occlusal trauma from the antagonistic tooth (Fig. 16-5).

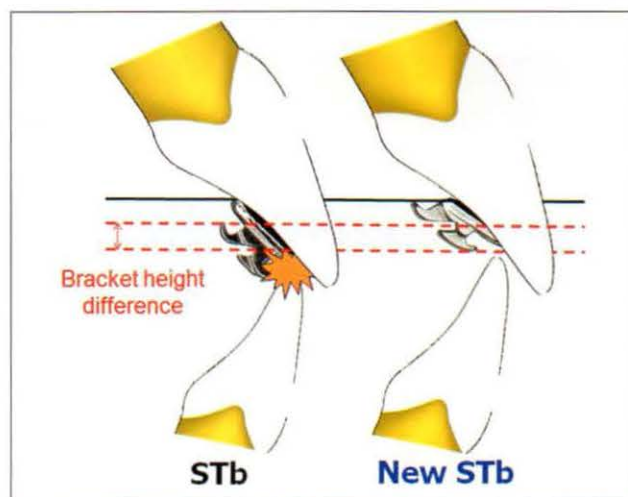


Fig. 16-5 The new gingival offset slot position reduces the in-out thickness

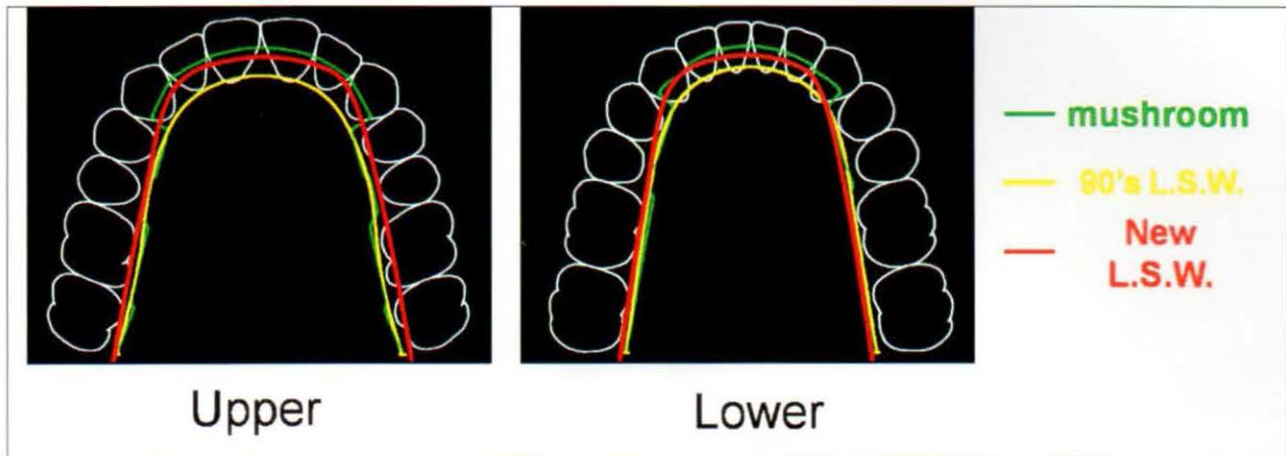


Fig. 16-6 Comparison of the mushroom, 1990s lingual straight wire (LSW), and new LSW archforms.

With the straight wire approach it is possible to minimize the thickness of the composite bonding material between the tooth and the bracket pad even in the canine area – it is less than 2 mm in most cases. However, this does not increase the risk of bond failure. Kim and co-workers have demonstrated that increasing resin base thickness up to 2 mm does not affect the strength of bracket bond to the lingual tooth surface in the indirect bonding technique (Kim et al 2000).

The new STb lingual straight wire appliance also permits simpler sliding mechanics, and eliminates the need for in-out bends between the canines and premolars, with more effective alignment and leveling.

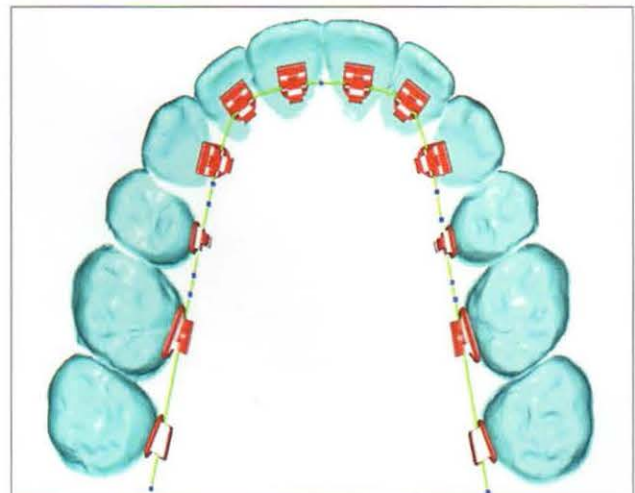


Fig. 16-7 A digital set-up.

Arch Form

When using the LSW method, it is necessary to select a lingual straight plane (LS plane) to determine the ideal bracket positions. The LS plane should be at two-thirds the level of the clinical crown height of the upper anterior teeth from the incisal edge and at the middle of the clinical crown incisogingivally for the upper premolars, upper molars and the lower teeth.

It is important to bond the bracket as near the lingual surface as possible to enable ideal bending of the wire, which should follow the shape of

the arch on the lingual side. Thus the new STb lingual straight archwire is more square-like in shape compared with the circular shaped archwire of the 1990s LWS bracket (Fig. 16-6).

Set-up Model

A computerized (Fig. 16-7) or a manual set-up (Fig. 16-8) must always be done while using the LSW technique. The set-up model must convey the following information accurately:

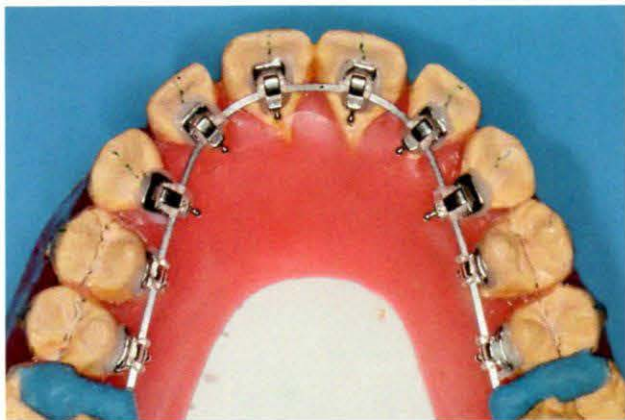
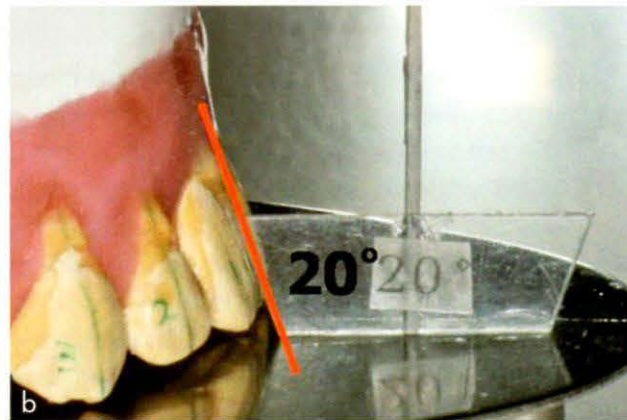
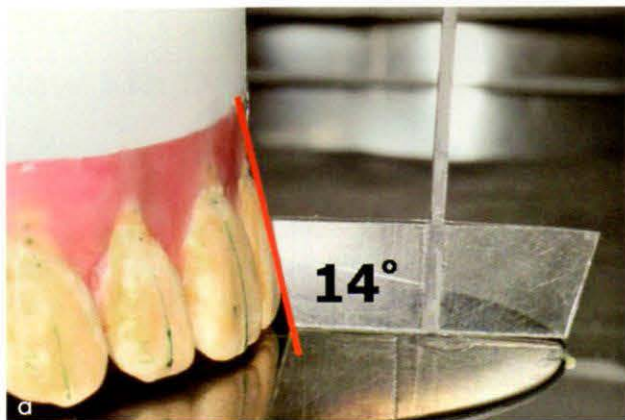
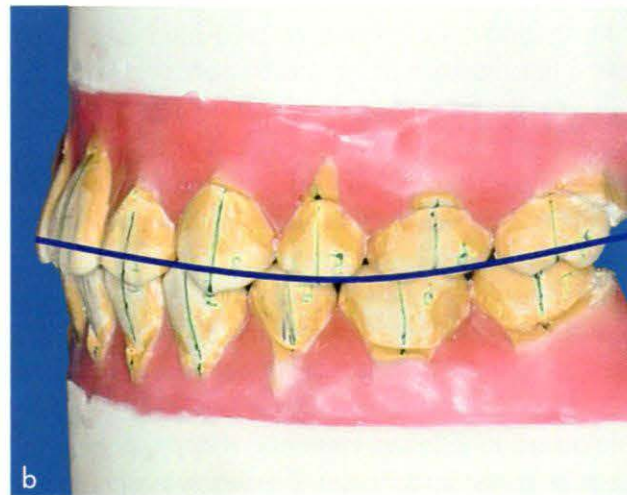
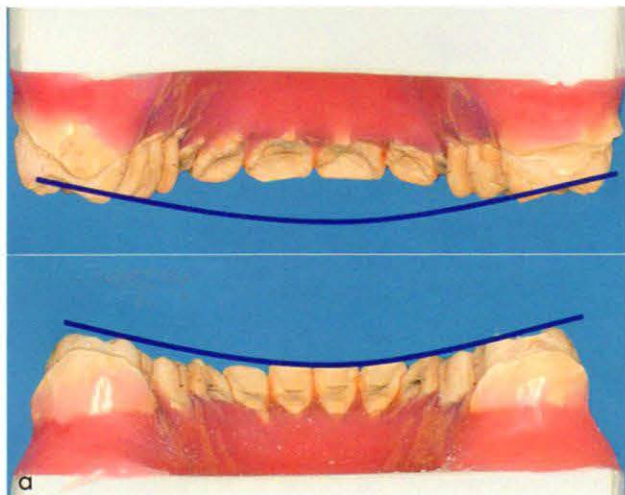


Fig. 16-8 A manual set-up.

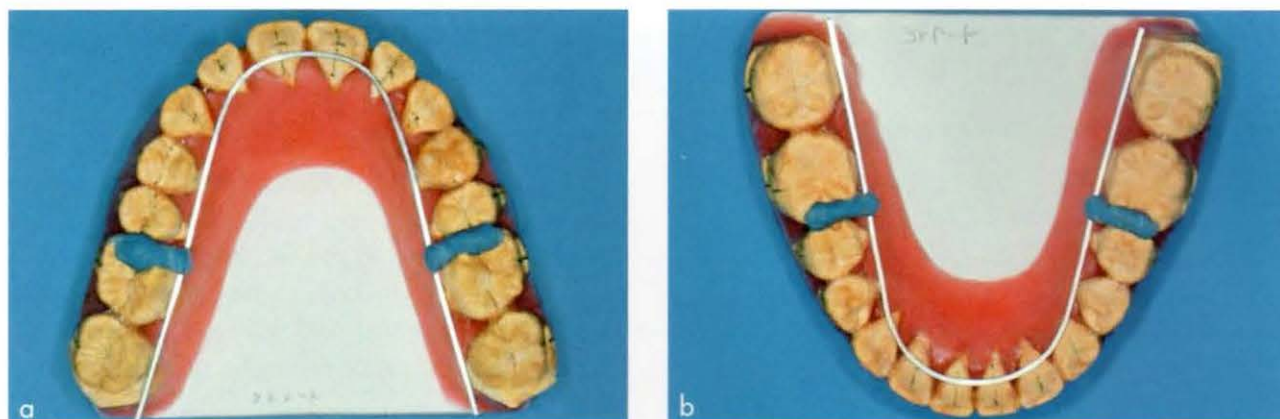
- Torque, angulation, height, and rotation (Figs 16-9a and 16-9b). (Over-torque and over-angulation are necessary for extraction treatment. However, too much torque in the anterior teeth on a set-up model leads to positioning the brackets almost on the gingival margin.)
- A mild Wilson's curve and a mild curve of Spee should be incorporated in the occlusal plane (Figs 16-10a and 16-10b).
- Arch form (a simple template is usually used to confirm symmetry of the arch form) (Figs 16-11a and 16-11b).



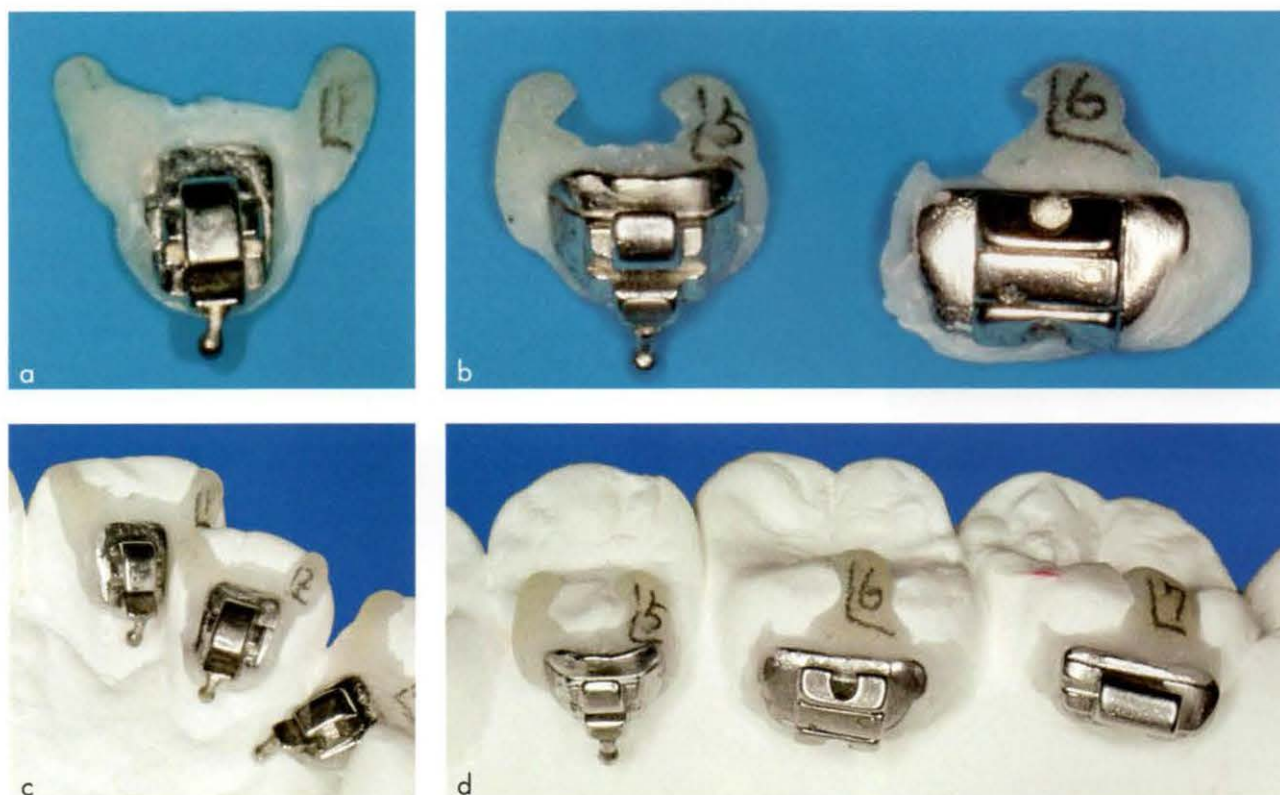
Figs 16-9a,b Establishing torque in a manual set-up.



Figs 16-10a,b Mild Wilson curve and mild curve of Spee by manual set-up.



Figs 16-11a,b Template being used to confirm symmetrical archform.



Figs 16-12a-d The KommonBase system developed by Dr. Komori.

Bracket Positioning and Bonding

After placing the brackets accurately on the set-up model, it is necessary to pay attention to the transfer of the brackets to the teeth. The KommonBase system, which was developed by Dr. Komori (Japan)

in 2008, is the latest indirect bonding method in lingual orthodontics (see Chapter 17). The KommonBase system allows customization, which includes the resin composite base of the lingual brackets. The glass ionomer cement used for bonding (Fuji Ortho LC) permits working in wet conditions and without etching (Figs 16-12a to 16-12d).

Wire Sequence

Non-extraction Treatment

- Leveling: 0.012 nickel titanium (NiTi) or 0.013 copper NiTi (CuNiTi)
- Rotation control: 0.014 NiTi or 0.016 NiTi
- Establishment of torque: 0.017 NiTi or 0.018 NiTi or 0.0175 titanium molybdenum alloy (TMA)
- Detailing: 0.016 TMA

Extraction Treatment

- Leveling: 0.012 NiTi or 0.013 CuNiTi
- Rotation control: 0.014 NiTi or 0.016 NiTi
- Establishment of torque: 0.017 NiTi or 0.018 NiTi or 0.0175 TMA
- Space closure: 0.016 × 0.022 stainless steel or 0.017 × 0.025 stainless steel
- Detailing: 0.016 TMA or 0.0175 TMA

Illustrative Case Reports

Case 1

A 30-year-old woman presented with a Class I malocclusion (Figs 16-13a to 16-13d) complaining of crowding of her front teeth. There was a partial crossbite involving the left lateral incisors and anterior crowding in both arches (Figs 16-14a to 16-14e, Figs 16-15a and 16-15b) (Table 16-1). Both arches were expanded using a quad-helix and a bi-helix.

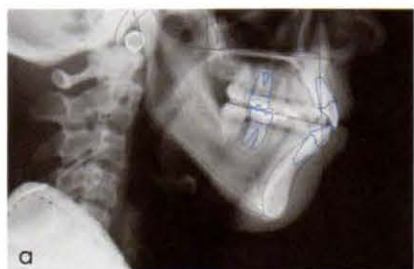
New STb brackets were bonded after expansion using the KommonBase method. The initial 0.012 NiTi archwires were shaped into the plain arch form and used for leveling (Figs 16-16a and 16-16b). These archwires were replaced with 0.016 NiTi to complete the leveling, and then maxillary and mandibular 0.0175 TMA archwires were used for detailing (Figs 16-17a and 16-17b). After 11 months of active treatment, her occlusion had improved (Figs 16-18 to 16-21) (Table 16-2).



Figs 16-13a-d Case 1: Pretreatment extraoral photographs.



Figs 16-14a-e Case 1: Pretreatment intraoral photographs.



Figs 16-15a,b Case 1: Pretreatment radiographs and superimposed cephalometric tracing.



Figs 16-16a,b Case 1: Maxillary and mandibular 0.012 NiTi archwires.



Figs 16-17a,b Case 1: 0.0175 TMA archwire for detailing.

Table 16-1 Case 1: Pretreatment cephalometric data.

Maxilla to Cranial Base				
SNA (°)	86.5	82.0	3.5	1.3
Mandible to Cranial Base				
SNB (°)	77.0	80.9	3.4	-1.2
SN - GoGn (°)	46.0	32.9	5.2	2.5
FMA (MP-FH) (°)	43.5	26.0	4.5	3.9
Maxillo-Mandibular				
ANB (°)	9.6	1.6	1.5	5.3
Maxillary Dentition				
U1 - NA (mm)	20.6	4.3	2.7	6.0
U1 - SN (°)	99.2	101.3	5.5	-0.4
Mandibular Dentition				
L1 - NB (mm)	187.3	4.0	1.8	101.9
L1 - GoGn (°)	96.3	93.0	6.0	0.6
Soft Tissue				
Lower Lip to E-Plane (mm)	50.2	-2.0	2.0	26.1
Upper Lip to E-Plane (mm)	-7.3	3.8	2.0	-5.5



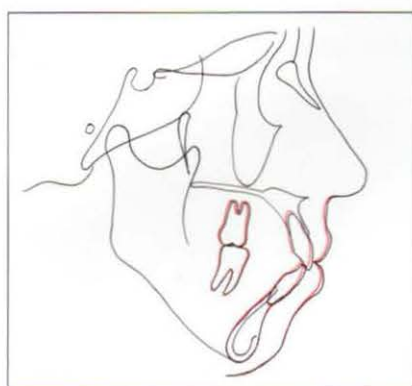
Figs 16-18a-d Case 1: Post-treatment extraoral photographs.



Figs 16-19a-e Case 1: Post-treatment intraoral photographs.



Figs 16-20a,b Case 1: Post-treatment radiographs and superimposed cephalometric tracing.



Figs 16-21 Case 1: Superimposed pre- and post-treatment (in red) cephalometric tracings.

Table 16-2 Case 1: Post-treatment cephalometric data.

Maxilla to Cranial Base				
SNA (°)	83.3	82.0	3.5	0.4
Mandible to Cranial Base				
SNB (°)	74.6	80.9	3.4	-1.8
SN - GoGn (°)	48.4	32.9	5.2	3.0
FMA (MP-FH) (°)	44.2	26.0	4.5	4.0
Maxillo-Mandibular				
ANB (°)	8.7	1.6	1.5	4.7
Maxillary Dentition				
U1 - NA (mm)	19.0	4.3	2.7	5.5
U1 - SN (°)	94.4	101.3	5.5	-1.3
Mandibular Dentition				
L1 - NB (mm)	167.2	4.0	1.8	90.7
L1 - GoGn (°)	95.0	93.0	6.0	0.3
Soft Tissue				
Lower Lip to E-Plane (mm)	66.4	-2.0	2.0	34.2
Upper Lip to E-Plane (mm)	-11.9	3.8	2.0	-7.8

Case 2

A 17-year-old boy complained of the esthetic appearance of his teeth. His medical history was unremarkable with no history of trauma or serious illness. Intraoral examination revealed that the maxillary dental midline was deviated to the left side with crowding in the upper and lower dental arches. A Class II molar relationship was observed on the right side while the maxillary left second premolar was in scissor-bite (Figs 16-22a to 16-22c, Figs 16-23a to 16-23e). The lateral cephalogram showed a Class

II skeletal malocclusion with a retrusive profile (Figs 16-24a and 16-24b) (Table 16-3).

The modified Pendulum appliance was used to derotate and distalize the maxillary first molars while a self-ligating appliance (Damon ORMCO) was used in the mandibular arch (Figs 16-25a to 16-25d). The upper arch alignment, leveling, and finishing was carried out using the new STb bracket system and LSV method (Fig. 16-26). The final occlusion showed Class I canine and molar relationships with ideal overbite and overjet (Figs 16-27 to 16-30) (Table 16-4).



Figs 16-22a-c Case 2: Pretreatment extraoral photographs.



Figs 16-23a-e Case 2: Pretreatment intraoral photographs.



Figs 16-24a,b Case 2: Pretreatment radiographs and superimposed cephalometric tracing.

Table 16-3 Case 2: Pretreatment cephalometric data-

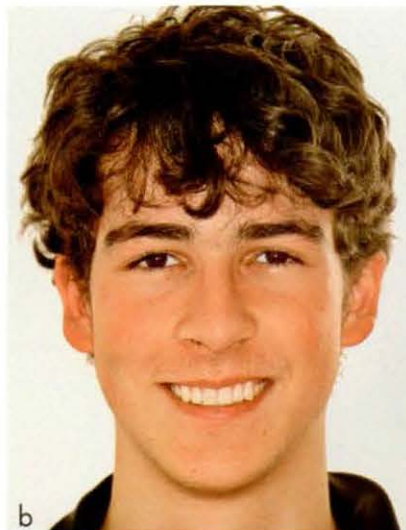
Skeletal Measurements				
Sagittal				
SNA (°)	84.7	82.0	3.5	0.8
SNPg (°)	82.4	80.0	3.5	0.7
Jaw Relation (ANPg) (°)	2.3	2.0	2.5	0.1
ANB (°)	4.2	3.0	2.5	0.5
Cranial Base (Ba) (°)	116.7	131.0	4.5	-3.2
Cranial Base (Ar) (°)	113.3	124.0	5.0	-2.1
Vertical				
Maxillary Inclination (SN-PP) (°)	8.2	8.0	3.0	0.1
Mandibular Inclination (SN-GoGn) (°)	32.7	33.0	6.0	-0.0
Jaw Relation (PP-GoGn) (°)	24.6	25.0	5.0	-0.1
Dentoalveolar Measurements				
Sagittal				
Overjet (mm)	8.9	3.5	2.5	2.2
Max. Incisor Inclination (°)	123.4	110.0	6.0	2.2
Mand. Incisor Inclination (°)	88.9	94.0	6.0	-0.8
Vertical				
Overbite (mm)	4.2	2.5	2.5	0.7
Maxillary Zone (°)	7.8	10.0	4.0	-0.5
Mandibular Zone (°)	25.4	20.0	5.0	1.1*



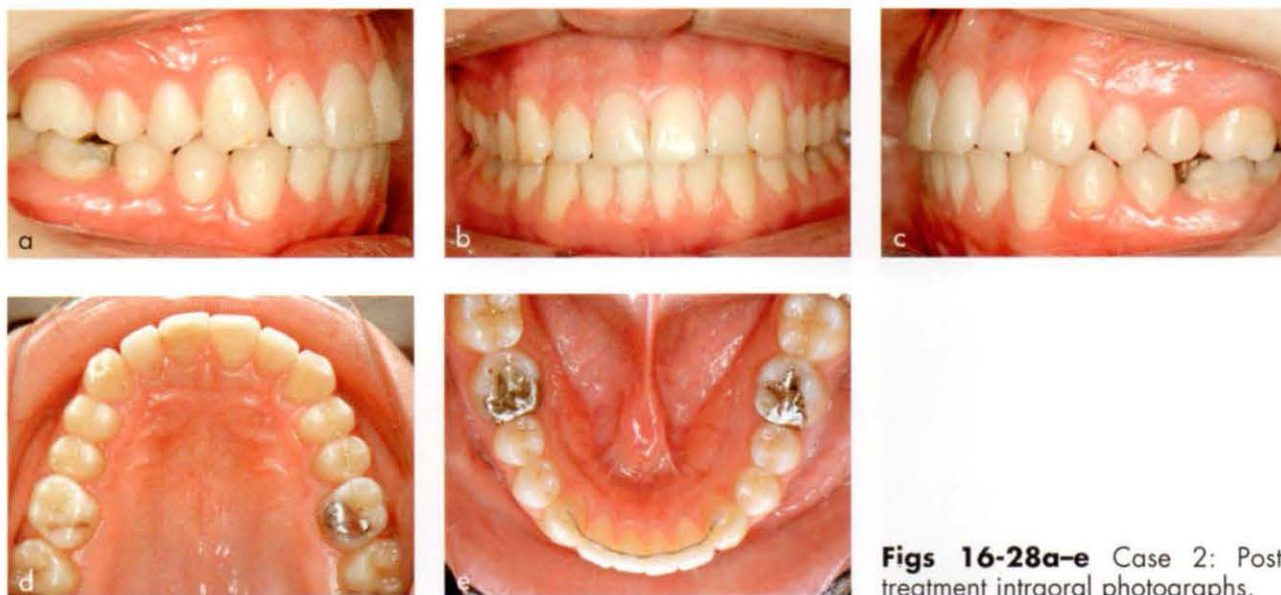
Figs 16-25a-d Intraoral view at the end of the distalization.



Figs 16-26 Upper arch treated with the new STb bracket system and the new LSW method.



Figs 16-27a-c Case 2: Post-treatment extraoral photographs.



Figs 16-28a-e Case 2: Post-treatment intraoral photographs.



Figs 16-29a,b Case 2: Post-treatment radiographs and superimposed cephalometric tracing.

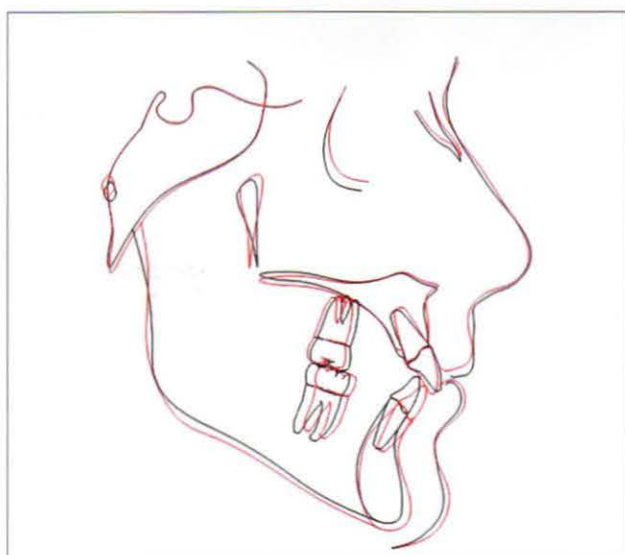


Fig. 16-30 Case 2: Superimposed pre- and post-treatment (in red) cephalometric tracings.

Table 16-4 Case 2: Post-treatment cephalometric data.

Maxilla to Cranial Base				
SNA (°)	85.3	82.0	3.5	0.9
Mandible to Cranial Base				
SNB (°)	81.1	80.9	3.4	0.1
SN - MP (°)	34.3	32.9	5.2	0.3
FMA (MP-FH) (°)	32.1	26.0	4.5	1.3
Maxillo-Mandibular				
ANB (°)	4.1	1.6	1.5	1.7
Maxillary Dentition				
U1 - NA (mm)	3.5	4.3	2.7	-0.3
U1 - SN (°)	108.4	101.3	5.5	1.3
Mandibular Dentition				
L1 - NB (mm)	8.5	4.0	1.8	2.5
L1 - MP (°)	91.3	95.0	7.0	-0.5
Soft Tissue				
Lower Lip to E-Plane (mm)	-5.9	-2.0	2.0	-2.0
Upper Lip to E-Plane (mm)	-9.9	3.9	2.0	-6.9

Conclusion

After more than a year's clinical experience with the new STb appliance system, it is clear that the new LSW method has several merits compared with treatment using mushroom-shaped archwires. We can now avoid complicated manipulation and archwire bending and the difficulty in upper and lower arch coordination.

In summary, use of the LSW method with due regard to the set-up model, bracket positioning and bonding and the new STb appliance system, not only reduces the clinician's chair-side time, but patients also feel more comfortable with the use of archwire without bends.

17 KOMMONBASE: NEW-GENERATION BRACKET BONDING IN LINGUAL ORTHODONTICS

Akira Komori

Among the challenges of lingual orthodontic treatment is the management and handling of the appliance. This is because the clinician cannot often directly see the lingual surfaces of the teeth and the morphology of the lingual surface of teeth not only varies among individuals but also presents several features including the cingulum in anterior teeth, marginal ridges, linguoincisor edge, and lingual grooves. Thus it can be difficult to place lingual brackets precisely. For these reasons, indirect bonding systems have become invaluable in lingual orthodontics.

Conventional Methods of Bonding Lingual Orthodontic Brackets

Many clinicians have made efforts to improve the individualization of the bracket base and techniques for indirect bonding in lingual orthodontics. A torque angulation reference guide (TARG) was designed to transfer bracket prescriptions from the labial surface to lingual surface at a given bracket height (Smith et al 1986). With TARG, to ensure a perfect fit, resin composite is used to fill the space between the bracket pad and a tooth surface. However, TARG is associated with some errors in the laboratory procedure. In patients with severe crowding, the prescriptions cannot be transferred precisely to the lingual surface, because the TARG gauge may not fit against the tooth surface. Furthermore, a large number of first-order bends were required in the archwire to obtain correct alignment, because TARG cannot transfer the labiolingual thickness of the teeth into the prescription.

The custom lingual appliance set-up service (CLASS) presented an improvement over TARG in the use of the laboratory set-up model with a given arch form (Romano 1998). The customized bracket base can compensate for the irregular lingual tooth morphology and incorporate tip, torque, and over-correction. In both TARG and CLASS, a silicone transfer tray is usually used for the indirect bonding. Since this tray transfers the prescription for all teeth in one arch simultaneously, any tooth movement resulting from expansion and extraction before bracket bonding may not be taken into account. In patients with severe crowding, some brackets require to be bonded after relief of crowding. Therefore, the use of the silicone transfer tray is not appropriate in these situations.

The resin core indirect bonding (RCIB) system utilizes individual hard transfer trays (Hiro and Takemoto 1998). In this system it is possible to bond brackets accurately, even in the case of tooth movements following extraction, expansion, and distalization, and in the presence of minor or moderate crowding. However, in a patient with severe crowding, the individual trays may not fit properly and may not be able to position brackets accurately. Many modifications of the RCIB system have focused on accuracy of fitting, reproducibility, and removability of the core. One advantage of the RCIB system is the ability to rebond in cases of bracket failure (Hong et al 2000; Kim et al 2000; Kyung et al 2002; Matsuno et al 2003; Echarri et al 2004; Prieto et al 2007). However, if the bonding system can ensure adequate bond strength, rebonding would not be necessary. However, the laboratory procedure of the RCIB system remains complicated and expensive.

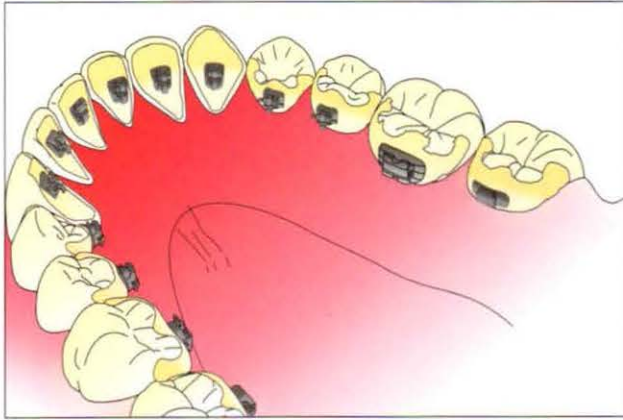


Fig. 17-1 An illustrative view of KommonBase.

Principles of KommonBase

Improvements in customized base design and bonding systems have led to the development of a precise direct bonding system, called "KommonBase". This system is based on three refinements to the dental materials used in lingual orthodontics:

- miniature lingual brackets, such as STb lingual orthodontic bracket – the low profile of brackets reduces occlusal interference and prevents bracket failure
- flowable resin, which originally developed as a filling material – flow and flexibility is remarkably suitable for KommonBase
- use of resin-reinforced glass ionomer cement as an adhesive for bracket bonding.

KommonBase is characterized by a large bonding base, which has been extended several-fold compared with the original bracket base. This helps achieve the best fitting, precise bracket positioning and maximizes bond strength (Fig. 17-1). Bracket failure is very rare. There is no need for transfer trays because of the self-positioning shape of KommonBase. In addition, the morphological complexity of the lingual surface is advantageous when using KommonBase. The many landmarks on the lingual surface of the teeth – cingulum, marginal ridge, linguoincisal edge, lingual groove, etc. – are used with KommonBase to determine bracket position. Bracket placement can then be done easily and accurately by applying pressure on the brackets

with an explorer. If the bracket is placed in an incorrect position, KommonBase can help direct it to the correct position. Even on mandibular incisors, which have poor morphological characteristics, good bracket seating can be achieved with KommonBase covering the linguoincisal edge.

Composition of KommonBase

KommonBase consists of three types of resin: high-flow filled flowable resin; low-flow filled flowable resin; and high-flow unfilled flowable resin.

The high-flow filled flowable resin ensures strong bonding at the interface between the bracket base and the resin composite, which can penetrate into the undercuts in the bracket base.

The low-flow filled flowable resin has good handling characteristics that prevent drifting of the reference wire and brackets in the laboratory.

The high-flow unfilled flowable resin is the "extended" part of KommonBase – the material spread over the lingual surface of the teeth very thinly, like a film, all around the bracket base. In cases of occlusal interference due to this extended part of the base, the resin abrades easily with normal occlusal function because it is softer than filled resin (Figs 17-2a and 17-2b).

High-flow unfilled, flowable resin was originally used for repairing the facing of a prosthetic crown. Since this unfilled resin is not available widely, high-flow filled flowable resin may be substituted for fabricating the extended part of KommonBase. However, self-grinding of any high resin spots is not to be expected with high-flow filled flowable resin.

Laboratory Procedure

Adhesion between the bracket and resin is maximized by sandblasting and metal priming of the bracket base, and coating with a high-flow filled flowable resin with a microbrush. KommonBase can be removed from the set-up model without fracturing the extended part, because the set-up model is

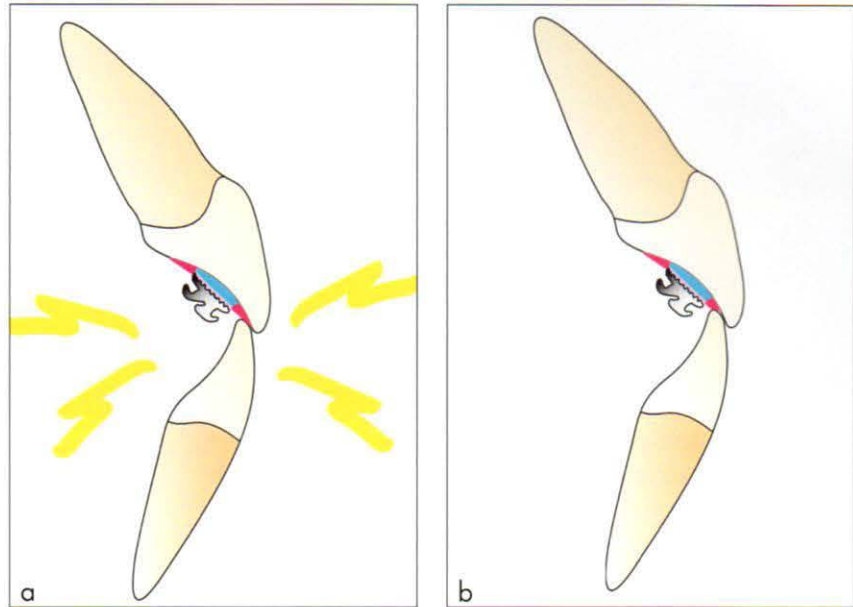


Fig. 17-2a,b Occlusal interference between KommonBase and the opposing tooth, which wears down naturally with occlusal function.



Fig. 17-3 Set-up model coated with soap solution. This procedure ensures that KommonBase can be separated from the model without contamination of the inner surface of the base.

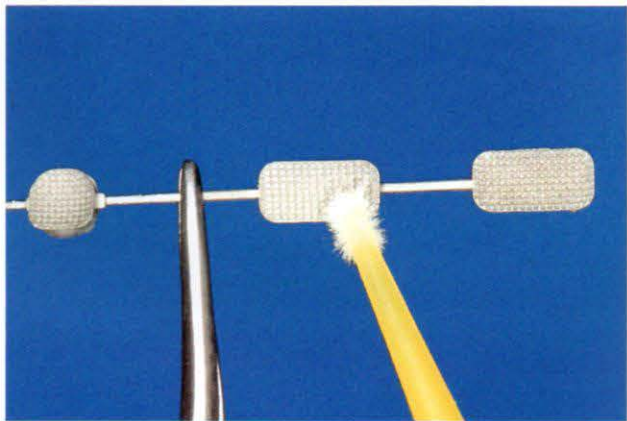


Fig. 17-4 After abrasion with aluminum oxide, metal primer is applied with a microbrush.

coated with a soap solution prior to applying the resin (Fig. 17-3). Use of separating medium is not recommended as this may lead to contamination of the inner surface of KommonBase, resulting in bond failure. Although the extended resin base is very thin, the base can be trimmed with an air turbine and diamond bur without the risk of fracture. Since trial fitting and adjustments are carried out in the laboratory, a

trial fitting patient visit is unnecessary. Therefore, with KommonBase, a reduction in chair-side time can be achieved. The procedure is as follows:

- After constructing the reference wires, the brackets are attached to it. Aluminum oxide abrasion (particle size 50 μm) and metal priming of the bracket base are carried out for enhancement of bond strength (Fig. 17-4).

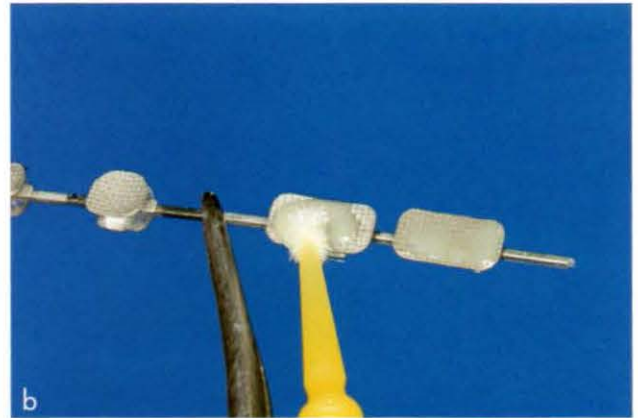
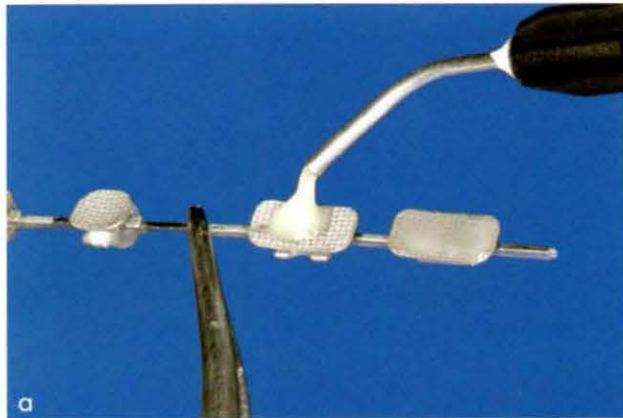


Fig. 17-5a,b A small amount of high-flow filled flowable resin is put on the bracket base and pushed into the undercuts with a microbrush.



Fig. 17-6 Low-flow filled flowable resin being put on the bracket base.



Fig. 17-7 Brackets stuck on the model.

- Then the bracket base is coated with a high-flow filled flowable resin (Gradia Direct Flo, GC, Japan) using a microbrush (Figs 17-5a and 17-5b).
- Next the low-flow filled flowable resin (GRADIA DIRECT LoFlo, GC Corp., Japan) is put on the coated bracket base (Fig. 17-6). This material helps the brackets and reference wire to adhere to the set-up model (Fig. 17-7).
- After checking the position of brackets and reference wire, the brackets are exposed to visible light to temporarily fix them to the model.
- The base is now extended with high-flow unfilled

flowable resin (Prossimo Add-On Gel, GC, Japan) (Fig. 17-8) and spread to the predefined landmark with an explorer (Fig. 17-9). The resin base is also extended vertically and anteroposteriorly.

- The set-up is exposed to visible light again.
- The brackets are then removed from the set-up model by holding the reference wire with a pair of tweezers (Figs 17-10 to 17-12). During this procedure, the KommonBase does not fracture, because flowable resin is flexible in comparison with conventional resin composite.

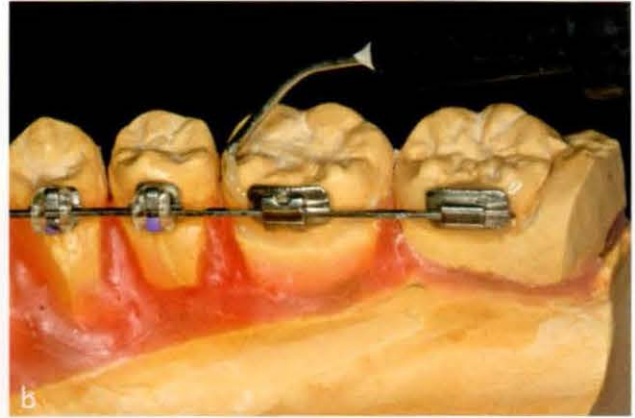
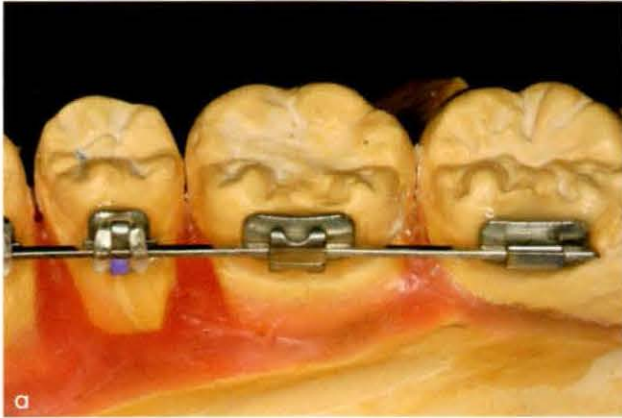


Fig. 17-8 High-flow unfilled flowable resin being applied close to the margins of the bracket base.



Fig. 17-9 Resin being manipulated with an explorer to extend it up to the landmark on the tooth.



Fig. 17-10 Brackets removed from set-up model.



Fig. 17-11 The extended resin base is very thin.

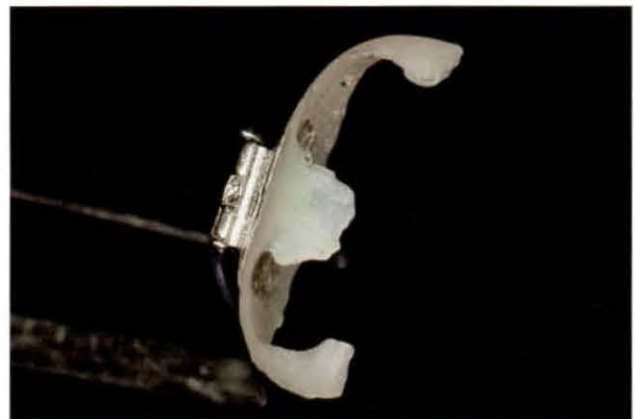


Fig. 17-12 Close-up view of KommonBase.



Fig. 17-13 Trial fitting of the brackets on the original model.



Fig. 17-14 Condition the tooth surface with 20% polyacrylic acid gel for 10 seconds.

- The brackets are detached from the reference wire.
- The brackets are fitted on the original model (Fig. 17-13) for a trial. If the neighboring teeth interfere in the placement, the KommonBase can be gently trimmed with an air turbine and diamond bur. With this procedure, trial fitting in the patient's mouth is unnecessary. Even though the bracket wing is very close to the adjacent tooth, the best fitting is achieved.
- Finally, the inner surface of the KommonBase is cleaned with absolute ethanol.
- Put RGIC on the inner surface of KommonBase. Figure 17-15 shows Fuji Ortho LC Paste PAK Automix (GC, Japan) being applied with a self-mixing tip.
- Place the bracket gently on the tooth. Then press it with an explorer to obtain the best fit (Figs 17-16 and 17-17).
- Remove the excess cement with the explorer (Fig. 17-18).
- Expose the bracket to visible light.
- Finally, the margin of KommonBase close to the adjacent tooth is checked with dental floss to ensure that RGIC has not flowed over the contact area.

Clinical Procedure

The clinical procedure involves placing the brackets, pressing each base against the tooth, and removing excess cement with an explorer. This is a simpler and easier procedure than placement of a labial fixed appliance, in which the clinician needs to inspect and verify the bracket position with a dental mirror. The procedure is as follows:

- Clean the teeth with fluoride-free pumice, and rinse and dry with a three-way syringe. This procedure can be substituted by air-powder polishing.
- Apply a conditioner consisting of 20% polyacrylic acid gel for 10 seconds, and rinse with a three-way syringe (Fig. 17-14).

Adhesives for KommonBase

Brackets should remain bonded firmly throughout orthodontic treatment, and also should be removed easily without enamel fracture at the end of treatment. Since lingual brackets are bonded closely to the gingival tissues, it is difficult to maintain a dry field during bonding. Although resin adhesives are capable of high bond strength, this is reduced by contamination with saliva, which leads to bracket failure. Adhesives that are not affected by the presence of water and saliva are clearly preferred. RGIC is a hybrid material of resin and glass ionomer cement, and its bond strength is not affected by



Fig. 17-15 The inner surface of KommonBase thoroughly coated with a glass ionomer cement.



Fig. 17-16 Bracket put onto tooth gently.



Fig. 17-17 Bracket pressed firmly with an explorer to obtain the best-fit position.



Fig. 17-18 Excess cement being removed with the explorer.

contamination with saliva and water (Bishara 1998; Cacciafesta 1998). Furthermore, RGIC releases fluoride and has the ability to absorb fluoride from topical fluoride applications, which allows it to act as a long-term fluoride reservoir (Attar and Turgut 2003). This feature helps prevent decalcification around KommonBase.

A commercially available RGIC for bracket bonding is Fuji Ortho LC. This material has water as one its contents, so the setting reaction may not

be affected by additional water. Since Fuji Ortho LC can bond to enamel with ionic bonding (Mount 1994), moist conditions are compatible with ionic bonding. Fuji Ortho LC Paste Pack Automix (GC, Japan) is a new generation of RGIC supplied as a two-paste material and self-mixing tip (Fig. 17-19). Its setting reaction is similar to Fuji Ortho LC.

Fuji Ortho LC requires measuring the powder with a scoop and mixing powder and liquid, which is not an easy procedure. Since the volume of



Fig. 17-19 New generation resin-reinforced glass ionomer cement: two-paste system with a self-mixing tip.



Fig. 17-20 Immediately after bonding, RGIC looks chalky.



Fig. 17-21 During treatment, RGIC is invisible.



Fig. 17-22 After debonding, the enamel surface is intact.

powder and liquid for each clinical procedure is different, the texture of the cement is not always constant. On the other hand, Fuji Ortho LC Paste Pack Automix produces a constant texture because of the two-paste system with self-mixing, which contributes to its ease of handling.

Figures 17-20 to 17-22 show the clinical application of KommonBase. There was no bracket failure in this case. Immediately after bonding, a small amount of excess RGIC looks chalky in dry conditions. However, it is not visible during treatment.

Debonding at the End of Treatment

Debonding can be carried out easily because the flowable resin in KommonBase is flexible in comparison with conventional resin composite. Immediately after debonding with lingual bracket removing pliers (Fig. 17-23), most of the KommonBase remains on the tooth. In the molar and premolar segments, the remaining resin is removed with adhesive removing pliers (Figs 17-24 and 17-25). However, it is difficult to approach the distal surfaces of the posterior teeth with conventional



Fig. 17-23 Debonding with lingual bracket removing pliers.



Fig. 17-24 In the molar and premolar regions, remaining KommonBase resin material is removed with adhesive removing pliers.



Fig. 17-25 Close-up view of the tips of conventional adhesive removing pliers.



Fig. 17-26 Newly developed adhesive removing pliers with a tapered tip.

adhesive removing pliers, so adhesive removing pliers with tapered tips have been developed for easy removal (Figs 17-26 and 17-27).

In the case of incisors with well-developed marginal ridges, it is difficult to remove KommonBase. However, since the extended resin base consists of unfilled resin, a low-speed handpiece and steel round bur (Fig. 17-28) can be used to remove the material. A small amount of remaining resin on the anterior teeth can also act as a suitable retention area for bonded fixed retainers (Fig. 17-29).



Fig. 17-27 The tapered tip can gain access easily to distal surfaces and prevents gingival irritation.



Fig. 17-28 On maxillary anterior teeth, the remaining resin is removed with a low-speed handpiece and steel round bur.



Fig. 17-29 A fixed retainer bonded with flowable resin.

Summary

In lingual orthodontics, indirect bonding systems have a significant role to play because of the morphological variations of the lingual surfaces of different teeth. Improvements in bracket seating and bonding systems have led to the development of a precise direct bonding system, called Kom-

monBase. KommonBase has a characteristically large bonding base, which can help achieve well fitted and precise bracket positioning. Furthermore, transfer trays are not necessary because of the self-positioning shape of this new system. KommonBase can serve as a useful alternative to conventional indirect bonding systems for the bonding of lingual orthodontic brackets.

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This book follows on from the authors' previous *Invisible Orthodontics* (2003) and charts the rapid evolution of the lingual technique using the new STb Light Lingual System and Lingual Straight Wire. A large portion of the book is dedicated to the characteristics and benefits of low-friction forces using STb, the first variable-friction lingual bracket.

The new STb bracket has been designed to improve patient comfort and give better clinical results and shorter treatment times. Furthermore, the growing worldwide demand for esthetic orthodontic treatment is encouraging more practitioners to exploit this technique.

A complete description of extractive and non-extractive mechanics, including the improvements in absolute anchorage control, completes this book.



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ISBN 978-1-85097-192-4



9 781850 971924
www.quintpub.co.uk